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Semi-Popular Articles

Utilization Abstracts

Book Reviews

The Principal Chinese Vegetable Foods and Food Plants of Chinatown Markets

The array of vegetable foods found in the Chinatown markets of New York and other large cities has not only excited the curiosity of those looking for exotic foods but also stimulated interest in the plants themselves.

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Introduction

The vegetable produce of the Chinese not only is varied but is strange to Occidentals. Lists of Chinese food plants and descriptions of them have been published at various times, but little has been written specifically about the Chinese vegetable foods bought and sold in our metropolitan Chinatown markets. They represent an interesting and unique collection of tubers, greens, melons, fruits, nuts, seeds, grains and other food products. Because the Chinese in their own country have had to squeeze every ounce of food possible out of the soil to sustain their lives, they have more thoroughly investigated available plants for their food possibilities than we of the West, and this explains the greater variety of the foods and food plants which they use.

A few of the vegetables sold, such as cabbage, found their way into Chinese markets in the United States many years ago, but a large number, because they do not appeal to American palates, because of difficulties in raising them as agricultural crops or perhaps merely because they are as yet unknown to the American farmer, are cultivated by Chinese truck gardeners exclusively for Chinese use, that is, for their own benefit or for Chinese-American restaurants. Some, however, are very good eating and deserve an opportunity to compete in American markets. Among the foremost promoters of Chinese vegetables for use in the United States was Dr. L. H. Bailey. Others, like F. N. Meyer, were of the opinion that it would take some time for the white race to acquire a taste for the majority of Chinese vegetable products. Foreigners living in China have made good use of some of the more delicate tasting vegetables, *e.g.*, water chestnuts and bamboo shoots, and upon their return have continued to eat them when they could be found.

This article does not attempt to provide a completely comprehensive treatment of all Chinese vegetable foods appearing in the markets, but an effort has been made in it to assemble and present some of the scattered information about those most commonly seen. The illustrations are photographs taken by Miss Fleda Griffith, formerly of the New York Botanical Garden, of samples collected by the author from the Chinese food shops in New York's Chinatown. The collection was made before World War II, when supplies of fresh, dried, pickled and candied articles of food were readily available. No exact estimate of the effects of the war on this supply is made, but it is apparent from the canned Chinese foods on the market put up in this country that, whatever the difficulties in keeping supplies moving, they

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have been in some measure overcome. Fresh greens, legumes and some cucurbits are locally raised for the markets on Chinese farms of Long Island, New York, and in scattered areas southward along the eastern seaboard. It is also reported that greens for the winter trade and some subtropical articles are supplied from gardens in Florida and even from Cuba.

In the following discussion the vegetable foods are divided into five groups *a*) cereal grains and other seeds; *b*) roots and tubers; *c*) shoots and greens; *d*) fruits and nuts; and *e*) cucurbits. If a plant contributes to two or more categories, it is discussed in its entirety when first mentioned. Algae and fungi used as foods are not discussed in this paper. All figures given in analyses are percentages.

Cereal Grains and Other Seeds

Rice. Rice (Mi) is the staff-of-life among the Chinese. It constitutes more than a third of their daily food and one-half of the vegetable part of their diet if the menus of all classes are averaged. Though not a purely Chinese food, it is from China that we have the earliest reports of it. The term " rice " is basic in the Chinese language and has come to mean " food " in general. Since earliest times the use of rice as food and its cultivation have spread over the whole world, and today there are many varieties. The earliest distinctions were made between glutinous and non-glutinous rice, also between water rice (Shui Mi) and dry or upland rice (Han Mi). The Chinese are very particular about their rice, and when moving from one part of the country to another, they usually carry their own with them.

The rice most commonly used is grown in water and is botanically known as *Oryza sativa* L. It is planted and germinated under water in small paddies before planting it out. The paddy fields, each surrounded by low earthen dikes, cover valley bottoms and flood plains, and even climb the hillsides by a succession of narrow terraces which follow the contour of the land. The water buffalo, which must spend a part of each day in the water for his own well-being, is still used to drag the ancient wooden plow through the muck of the paddies. In some areas two and even three crops are raised and harvested annually. When ripe, the grain is beaten out by the ancient method of flailing, and the beaten ears are tossed into the air so that the chaff is blown free. The methods of rice-growing in China do not change with the passage of time.

The rice bought in Chinese markets is mostly polished rice, but there is some unpolished (whole or rough) rice sold also. The rice stocked in the grocery stores of American cities, unless otherwise designated, is polished. According to Chinese custom, only polished rice is fit to be eaten; unpolished rice is eaten only by coolies and livestock. Westerners, however, find the latter more healthful, though the former is the basis of many dishes. An unvaried diet of polished rice causes beri-beri, and many of the poor Chinese contract the disease for this reason. It is energy-giving but has little food value. It lacks not only vitamin B_1 but also other vitamins. As seen from analyses, whole rice is recommended on account of its definitely superior content of vitamins, salts and protein.

Whole or rough rice is the product after threshing. To polish it, the rice is milled. Milling removes the rough bran and polishes it white. In the process, first the hull and then the germ and all the layers of bran are removed except a part of the last layer. Only the starchy part of the kernel is left, surrounded by a part of the last seed-coat layer which is very rich in protein. Milling removes only about 10% of the protein. When

the germ is removed with the bran, 85% of the oil content of the kernel is lost. It is of note that rice-bran oil has been used in the cosmetic industry as an ingredient in shampoos to prevent removal of natural oils from the scalp. The oil is claimed to possess excellent skin-lubricating action and to be particularly effective for nourishing the skin. Unpolished rice contains a fair amount of vitamins A and G, and is a good source of vitamin B. The calorific value per 100 gm. of rice averages approximately 350.

Besides rice in its usual cooked form, it is also eaten as congee and as a breakfast food in the form of puffed rice. Congee is a thick gruel made from prolonged boiling of rice and is an almost universal staple of the Chinese breakfast, being eaten with a relish of salted vegetables or bean curd. It is easily digested and fattening, and as a diet for the sick it is most excellent, being demulcent, cooling and nourishing.

Rice is said to benefit the breath, remove anxiety and thirst, check discharges, warm the viscera, harmonize the gases of the stomach and cause the growth of flesh. Lixiviated ash of rice straw is used as an antidote in arsenical poisoning. Rice straw is a useful roofing material, and there are many farm dwellings in Central and South China whose roofs are thatched with it. It also makes an excellent packing material for glassware and china, and is used for fuel.

Glutinous rice (No Mi) is used for distilling spirits, for pastry, for sweetmeats, for dumplings and as puffed rice. Chinese puffed rice is not so large as American puffed rice, being enlarged only to about twice the size of the ordinary grain. In China it is the foundation of candy balls, also a sticky confection sold by street vendors in strips or cakes. Cakes made of this rice and fried in camel's fat are used for hemorrhoids. Congee is used in fevers as a diuretic, and both internally and externally as a demulcent. Rice flowers are dried and used as a dentifrice and cosmetic. Ashes of the hulls serve to clean discolored teeth.

Analyses of polished, whole and glutinous rice are as follows:

	Oryza sativa L.		*Oryza montana* L.	*Oryza glutinosa* Lour.
	Polished 1st grade	**Whole rice**	**Upland rice**	**Glutinous rice**
Water	12.25	9.8	13.78	14.20
Protein	7.29	7.3	7.12	5.88
Fat	0.46	2.0	0.26	1.41
Carbohydrate	79.16	66.9	77.40	77.18
Crude fiber	0.18	8.6	0.68	0.20
Ash	0.66	5.4	0.76	1.13

Soybean. An important and useful Chinese food sold in Chinatown and now thoroughly established and grown as a domestic crop in the corn belt of the middle western United States is the soybean, *Soja max* (L.) Piper. Once honored as one of the "five grains" sowed by the Emperor of China as part of the ritual performed at the vernal equinox ceremonies in old Peking, it now has a highly esteemed place as a raw material in the industrial world. Besides food, it constitutes an important basic material in the manufacture of soaps, oil, plastics, rubber and many other useful products.

Since early days people have exploited the soybean. It is referred to by the Chinese as "the poor man's meat and the poor man's milk". Since then the food aspects have been elaborated upon,

and soybeans are now served in more than 400 tasty ways by Chinese housewives. In New York the soybean is sold in the Chinese shops mainly in three forms: seeds, bean sprouts and bean curd. Soy sauce and soybean oil can also be obtained. The former is a heavy dark fluid which is used as a condiment to supply saltiness that brings out flavor, and the latter serves in cooking like other oil or butter, and also for lighting lamps.

In the United States the first reference to soybeans was made by James Mease in 1804. While the white, green, black, brown and spotted varieties were the first of importance, there were 16 subvarieties based on differences in form, size and color. Now 2,500 forms are known, out of which 100 named varieties are handled by domestic growers and are the objects of much investigation by the Federal Government's Agricultural Experiment Stations.

The soybean as food is very important because of its high protein content. Not only do the beans provide good food, but the germinated seeds, known in the markets as "bean sprouts" (Fig. 1), provide a most palatable vegetable when cooked. These have become so popular that they are now canned and sold in American grocery shops. Bean cheese, or curd (Tou-fou), from soybeans is also eaten (Fig. 2). In the Chinese shops bean curd is kept in empty kerosene tins under water. To make it, soybeans are soaked in water three hours, reduced to a paste, then cooked. After being strained through a coarse cloth, the milky white filtrate, rich in protein and fat, is treated with crude salt (magnesium chloride). The protein material is precipitated, and the coagulated mass is pressed and kneaded into small cakes. The cakes may be dipped for a few moments into a saline solution of curcuma. A filtrate from cooked soybeans resembles milk and is known as "soybean milk". When heated, a skin such as forms on milk rises to the surface. For many purposes it can be successfully substituted for cow's milk.

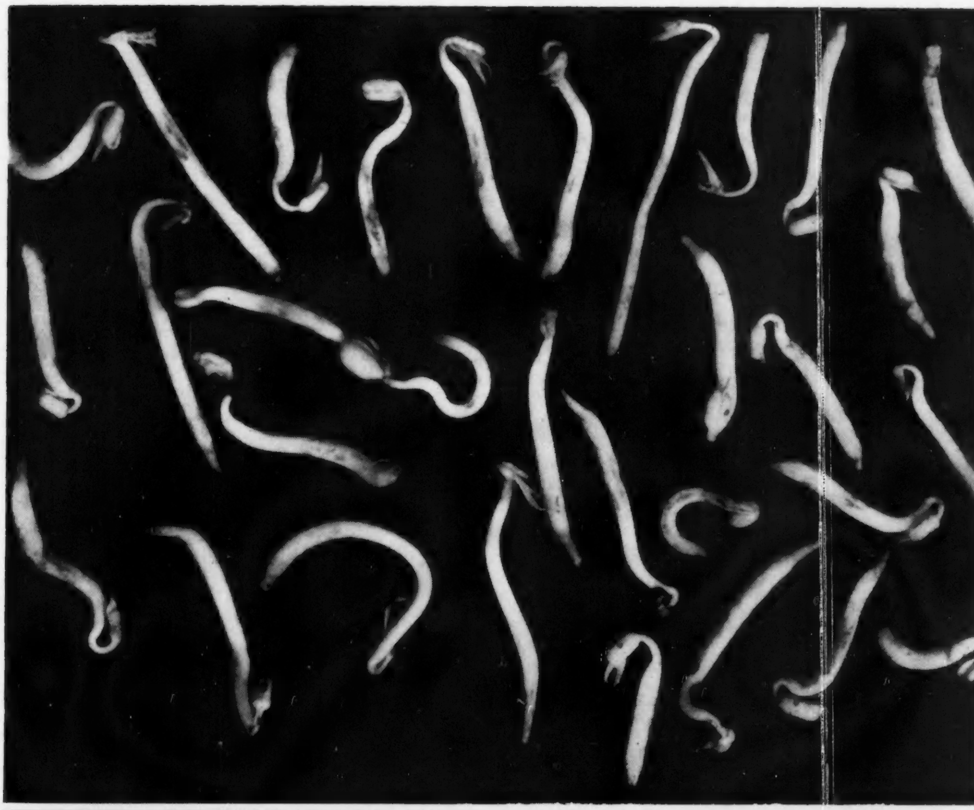
Food uses of soybeans, such as flour and meal, should be mentioned. It is said that as high as 20% of soybean flour can be used in making bread without changing the flavor while increasing the protein content from 6% to 12%. This bread is said to be good for diabetics. Soybean flour contains four times as much protein as oat flour, *i.e.*, 52.20% to 13.87%, and about one-fifth the amount of fat (1.2% to 6.18%). The manufacture of soybean flour yields an important by-product, lecithin, which is a fat rich in phosphorus and very useful in the preparation of certain foods and medicines. It is commercially less expensive than lecithin obtained from eggs.

Analyses of soybeans give the following results:

Moisture	8.88
Protein	42.20
(True proteids	31.28)
Fat	13.36
Fiber	5.20
Carbohydrate	26.13
Ash	4.23
(Starch	small quantities)

Analyses of four food products of soybean are shown in the following tabulation:

	Water	Protein	Fat	Carbohydrate	Undet.
Bean cheese (Tou-fou)	76.15	13.15	7.09	1.40	...
Soybean milk	93.10	3.13	1.89	0.51	...
Bean oil (Tao-yu)	57.12	7.49	...	18.76	...
Soy sauce (Tao-jung)	62.86	12.67	1.21	6.71	2.77



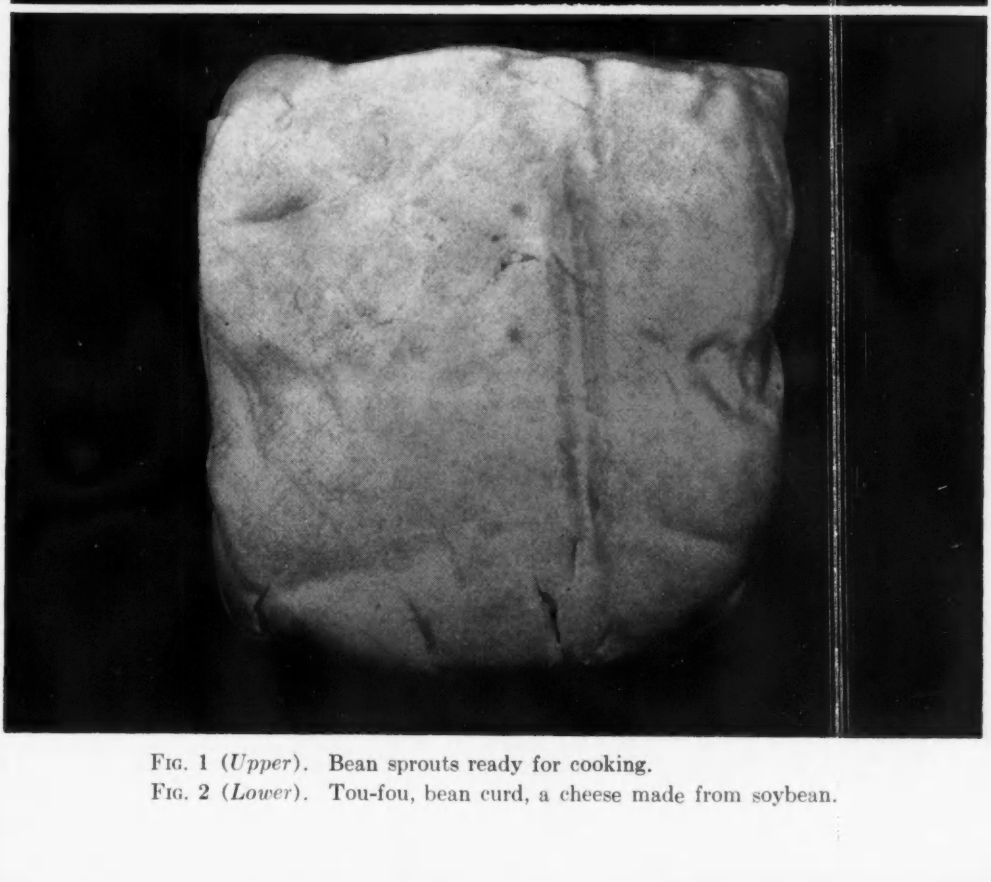


FIG. 1 (*Upper*). Bean sprouts ready for cooking.
FIG. 2 (*Lower*). Tou-fou, bean curd, a cheese made from soybean.

According to Jones, dried soybeans contain potassium, sodium, calcium, iron, copper, magnesium, phosphorus, sulphur, chlorine, manganese and zinc. Another analysis for mineral content shows that yellow soybeans contain 0.49% aluminum as aluminum oxide, about the same of iron as iron oxide, 7.45% calcium as calcium oxide, and 7.34% magnesium as magnesium oxide. Soybean sprouts contain 0.43%, 10.96% and 8.63% for the same minerals, respectively.

The nutritional merits of the soybean are further evident in some figures found in a Chinese study of several important food plants. The biological value of soybean curd is designated as 65, and the coefficient of digestibility is 96. Soybeans are a good source of vitamin B, and they contain a small amount of vitamin G. Tests made with Chinese mice have shown both yellow and green soybean sprouts to be abundant sources of vitamin B. In other tests soybean curd (Tou-fou) was shown to possess a fair amount of vitamin A. Soybean oil contains little vitamin A or vitamin D. The fuel value of soybeans per pound is 1,985 calories.

Because of the industrial importance of soybeans and soybean products, some account should here be given of the uses to which they are put. The property of nitrogen-fixation in the nodules on the roots of the plant makes soybean a useful green manure and helps other plants associated with it to grow better. Since the nitrogen content of plants with nodules is 2.78% as compared with 1.77% in plants without nodules, the former are important as hay and forage for animals. Soybean hay contains 11.7% digestible crude protein as compared with 10.6% for lucerne hay and less for others. Oil beancake, after the oil has been expressed, is used for fertilizer and also for animal food. The crude soybean oil, besides its use in cooking, goes mostly into the manufacture of soap. It is said to give to soap the property of lathering, even in a 3.5% concentration of salt. In the manufacture of soft soap, soybean oil is superior to linseed oil, and in the manufacture of hard soap hydrogenated soybean oil is recommended as the best substitute for beef tallow.

Soybean meal is the raw material from which two important basic industrial products are made, a plastic and a fiber. Soybean meal with 9.28% moisture content plasticizes when subjected to 100° C. and a pressure of 5,000 pounds per square inch for five minutes. When plasticized, it sems to exhibit flow with the moisture content as low as 1%. For this reason the plastic does not fracture spontaneously on drying; it holds its shape well and is almost transparent. The only disadvantage has been that plastics made from either soybean meal or soybean protein are hygroscopic. Most of these plastics go into the manufacture of automobiles. The protein fiber from soybeans has the advantage, on the other hand, over those synthesized from cellulose of cotton and wood, in that the protein fibers are warmer and retain their shape longer. Furthermore, under controlled conditions the yield of protein fiber from plants will be 100% steady in contrast to that of animal protein fiber which is known to be variable. It is interesting to note that 200 pounds of soybean wool can be produced on the same amount of land that will yield only five pounds of sheep's wool. During the war about 1,000 pounds of soybean wool were produced each day, and all of it went into winter uniforms for the armed forces.

Thirty-six different varnishes containing 100% of their oil content from soybeans have been developed and given exposure tests. The acid-, alkali-, and water-resistance of many of these oils is excellent, but their drying is not so rapid as that of the super-quick lacquers which are so popular. Soybean oil is also the

basis of a capital substitute for rubber. The rubber-like material made from soybean oil, known as " norepol ", has a tensile strength of about 500 pounds per square inch. It also exhibits good resistance to abrasion and is impervious to water and alcohol so that it can replace rubber in such products as insulation, shoe heels, fruit-jar rings, gaskets and tubing.

One of the more recent achievements in the exploitation of soybean protein has been the production of a stabilizer in foam fire-fighting apparatus used against burning oil tanks and on ships. World War II was chiefly responsible for this advance. Over 5,000,000 gallons of foam liquid were produced during the war, and in 1944 alone 900,000 bushels, or 40% of the total industrial consumption of soybeans in that year, were thus used. Other uses, too numerous to mention, include enamels, printing ink, linoleum, shortenings, margarine, foundry cores, glycerin, billiard balls and notepaper. In general values the crops of soybeans and the by-products derived therefrom in the United States represent an annual total income of $45,000,000.

Mung Beans. Two kinds of mung beans are found in the food shops of New York's Chinatown, the green variety and the red. The former is botanically known as *Phaseolus mungo* L. var. *radiatus* Bak., the latter as *P. mungo* L. var. *subtrilobata* Fr. et Sav. Their Chinese names are, respectively, " Lu Tou " and " Hung Tou " or " Ch'ih-hsiao Tou ". These small edible bean seeds, almost spherical but flattened at both ends, are grown in China between rows of sweet potatoes and cotton, and ripen before either of the latter crops is ready to be harvested. Not only are the seeds edible and nutritious, but the green pods are also eaten. Over a hundred kinds of mung bean are grown in China and other Asiatic countries. In the United States the crop is becoming of increasing importance as a forage plant. The Hung Tou is good food for donkeys but is too heavy and heating for mankind.

Bean sprouts bought in the markets for eating are mostly from mung beans. The sprouts are made by soaking the beans in water, and are used in soup and as an ingredient in other Chinese dishes. They are also good cooked as a table vegetable with milk. The green mung bean is often ground into flour and can be used for making the kind of vermicelli known as " Fen-t'iao ".

The mung bean contains proteins that are biologically complete and thus is superior to many other members of the bean family; it is reportedly deficient, however, in lime and sodium chloride. The following is an analysis of the green mung bean, green mung sprouts, and the red mung bean:

	***Phaseolus mungo* L. var. *radiatus* Bak.**		***Phaseolus mungo* L. var. *subtrilobata* Fr. et Sav.**
	Green bean	**Bean sprouts**	**Red bean**
Water	9.88	93.22	14.91
Protein	22.97	2.50	19.06
Fat	1.50	0.15	0.76
Carbohydrate	57.78	3.18	57.40
Crude fiber	4.04	0.63	4.44
Ash	3.83	0.32	3.43

The calorific value per 100 gm. is 345 for the green mung bean and 321 for the red. Mung bean sprouts, while they are a good source of vitamins B and C, and

fair in A, have a calorific value only of 25. The green mung is fair in vitamins A, B and G, but low in C; the red mung is fair only in vitamins E and G.

Medicinally Lu Tou is considered to be a resolvent, carminative, antifebrile and counter-poisonous remedy. It is prescribed for lesions following smallpox, obstinate dysentery, bladder difficulties in the aged, and all sorts of poisons. Bean meal is similarly used and is highly regarded as a poultice in boils and abscesses, and as an antivinous remedy. The seed coat alone is considered antifebrile and is used in opacity of the cornea. The pods are used in obstinate dysentery, the flowers to counteract the effects of wine, and sprouts are considered to be countervinous and antifebrile. The leaves are steeped in vinegar and used in cholera. The Hung Tou is said to drive away dropsy and scatter carcinomatous and purulent swellings. It is prescribed in even a larger number of similar difficulties than the Lu Tou; many of these are obstetrical, such as threatened abortion, menstruation during pregnancy, difficult labor, retained placenta, post-partum trouble and non-secretion of milk. The leaves are recommended in fever and urinary difficulties, and the sprouts in threatened abortion, whether from abortive tendency or from injury.

Lotus. Lotus seeds (Lien Tzu), the "beans" that Pythagoras was said to have once forbade his disciples to eat, constitute another delicacy found in the Chinatown food shops (Fig. 3). They are produced by the Chinese lotus, *Nelumbium speciosum* Willd., and are about the size of a marble, white after the coverings are removed. The germ (plumule), which is green, must be removed because it is very bitter. Though they are an expensive luxury reserved for the rich, the poor man on special occasions may enjoy candied lotus seeds, or Bakpao Fan, a kind of pudding with "eight precious" ingredients, of which one is lotus seeds. They are eaten raw, candied, roasted, boiled or ground into flour, and are considered nourishing and highly beneficial to bodily health and strength, in promoting circulation and strengthening virility.

The composition of dried lotus seeds is:

Water	8.72	Carbohydrate	58.14
Protein	16.64	Crude fiber	3.15
Fat	2.44	Ash	3.03
		Undetermined	7.88

The viability of lotus seeds is well known. Experimenting with lotus seeds discovered buried deep in the soil of a certain district in southern Manchuria, one Japanese authority states that seeds buried at least 120 years had retained their vitality and that all seeds used in the test germinated without exception. After filing the seed coat the first signs of germination appeared in about four days.

The rootstock of the lotus is another food on sale (Fig. 4). It looks like links of a large sausage and is bought raw in bulk, boiled and sold in slices, or preserved dry in slices (Fig. 5) for future shipment to other localities. The "arrowroot" made from the fleshy rhizome is called "Ou-fen" and is aromatic and sweet. It is held to be nutritious and a good tonic, increasing the mental faculties and quieting the spirits, and is believed to be of great value in the treatment of diarrhea and dysentery. It is also given for diseases of the chest and as an ingredient in a food prepared for infants who can not be nursed. Ou-fen is made by crushing the root, washing the starch out with water, and allowing it to settle until the water can be poured off.

The fresh rootstock is 84.2% water. An analysis of the water-free residue shows it to contain protein, 9.9% (albuminoids, 5.8%); fat, 1.2%; carbohydrates, 65.0%; crude fiber, 4.8%; ash, 4.8%; and undetermined substances, 14.3%. Their fibrous nature and failure to soften after prolonged boiling prevent

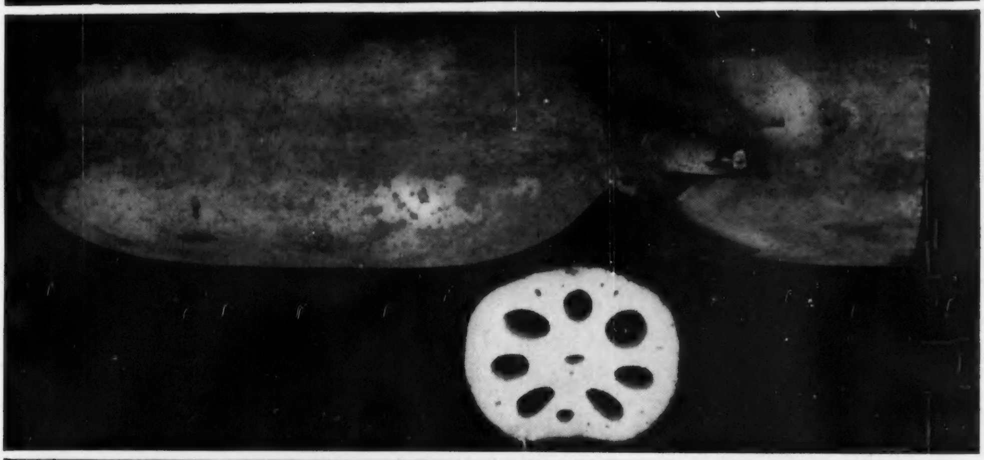


FIG. 3 (*Upper*). Dried lotus seeds.
FIG. 4 (*Center*). Fresh lotus root. Slice shows internal structure.
FIG. 5 (*Lower*). Dried slices of lotus root as sold in Chinese grocery stores.

these roots from being a satisfactory food from the American viewpoint. There has been considerable research on the vitamin C content of lotus roots and lotus seeds. From feeding tests made on guinea-pigs with the juice of lotus root, 10 cc. daily was found to be antiscorbutic. By microchemical tests confirmation of the vitamin C content was obtained not only for lotus roots but also for lotus seeds.

Ginkgo Seeds. One of the most celebrated trees from China is the ginkgo (*Ginkgo biloba* L.). It not only is his-

torically famous, produces beautiful white satiny wood and has a soil conservation value, but it also produces edible seeds, called "Pak-Ko" (white fruit), which are sold in food shops. Ginkgo is dioecious, that is, any one tree produces only male or female flowers, and the fruits are therefore borne only on the female. When ripe they are about the size of small plums and golden in color. They are gathered when they fall and thrown into a vat of water where they are allowed to ferment. The odor of the decomposing pulp is very offensive, but this process facilitates extraction of the seed.

The pulp contains a series of fatty acids from formic to caprylic, including acetic and butyric, and has been known to cause severe cases of skin poisoning. Besides having a resinous quality the fruits are bitter to the taste and are astringent in effect.

The seeds are two- or three-angled, white and thin-shelled. The Chinese say that the three-angled seeds produce male trees, the two-angled, female trees. The seeds when eaten raw are toxic to some people, causing a dermatitis or swollen glands, and on rare occasions have even proven fatal. In order to be eaten safely, they must be cooked or roasted. Americans do not fancy ginkgo seeds, but both the Japanese and Chinese eat them as an appetizer, as a tasty ingredient in certain dishes, or after the meal to aid digestion. The seeds will germinate readily when planted, but growth is slow and struggling. Suckers from the base of an old tree grow much more vigorously.

The kernel of the ginkgo seed contains only starch, whereas those of most other conifers contain oil. The dry kernels have 62% to 68% starch, 6% cane sugar, 11% to 13% protein, and 1.5% to 3.0% fat. It has been reported that the Chinese use the seeds to wash clothes and that the seeds may be digested in wine or oil to make a kind of detergent cosmetic by virtue of the fatty principle in them.

Roots and Tubers

Yam Bean. Among the tuberous forms of plant food found in Chinese shops, the yam bean (*Pachyrhizus erosus* (L.) Urb.), called "Fan-Ko", has achieved a high place. The fleshy root is nearly globular (Fig. 6) and its flesh is firm and

FIG. 6. Yam bean tuber.

sweet, but it is tough, a disadvantage so far as American palates are concerned. Generally it is the young tubers which are eaten, while the older ones are principally used as a source of starch which is of superior quality. The starch is present in nearly spherical grains which appear singly or in compound form and do not show stratification, a diagnostic character of the yam bean. An analysis of original material from the tubers gives the following results:

Water	78.09	Carbohydrate	14.00
Protein	2.18	Crude fiber	1.43
Fat	0.80	Ash	0.80
		Undetermined	3.31

The pods of this legume, because of their hairs, can not be eaten without causing diarrhea. The seeds contain a small amount of poisonous resin, a very active fish poison, and from the twining stem the natives of Fiji derive a tough fiber which is used in making fish-nets. No medical uses are known for this plant.

Kudzu. Another leguminous tuber-bearing plant is the kudzu vine, *Pueraria Thunbergiana* Benth. It is fast-growing, bears papilionaceous purple flowers, and has some ornamental value. It is chiefly used as a source of starch and is said to have industrial possibilities for paper manufacture. In New York's Chinatown kudzu appears on sale in the form of long potato-like tubers, trimmed at both ends (Fig. 7). The roots may branch and grow to great length, assuming grotesque forms.

As a source of food for American tastes the roots do not make a suitable vegetable, since they contain a great deal of fiber, and no amount of boiling will make them soft. Then can, therefore, be used only for the starch which they yield. The fresh roots are reported to contain 40% of starch. A kind of flour called " Ko-fen " is made of this starch. The starch swells in water, and one teaspoonful is sufficient to make a large dish of soup. It is sweet to the taste, fine and without odor. In Japan the vine is used as a forage plant for cattle. Because of its capacity to adjust to growth in dry and poor soils, it can be used to form pasture.

The fibers from the inner bark of the vine can be made into a " grass linen " similar to that made from the fibers of *Boehmeria nivea* Gaudich. The cloth is called " Ko-pu " and because it is smooth and does not cling to the skin, it is favored for summer wear. Use of the fiber for making paper has also been reported. In Japan the young branches may serve as a binding material in much the same way osier branches are used. One of the modern uses of kudzu vine is in the prevention of gullying; it thus serves an important purpose in current anti-erosion programs. Its rapid growth and its capacity to root at the nodes as it grows over the ground make it a valuable soil-binding plant. Soon after rooting bacterial nodules appear on the newly formed roots. Consequently this plant can render great service as a green manure by its capacity to enrich the land in nitrogen.

Fig. 7. Kudzu root bought in New York's Chinatown.

According to ancient medical practice in China, colds, fever, influenza, dysentery, snake and insect bites are treated with a decoction made from the root. It is also taken as an antidote for poisonous drugs, such as croton oil, and is applied in cases of dog bite. The seeds, shoots, flowers and stems also have medical use.

Taro. One of the oldest food plants is taro (*Colocasia esculenta* (L.) Schott.*), an important root crop for millions of people for well over 2,000 years. The first known records come from China where it is called " Wu ". It spread from the continent of Asia to Japan, south to Malaysia, then east and west to all parts of the tropical and subtropical world. Cultivation of Yu-t'ou, another name for taro in China, has been reported through central and south China.

The plant is a stemless aroid with tufts of large heart-shaped leaves which spring from a central underground corm surrounded by a cluster of tubers. It flowers rarely and has never been observed to produce seed, though reference to seed is made in Chinese literature. Taro is grown for its tubers. It is propagated vegetatively by separating them from the mother plant and planting them individually. Today there are probably about 1,000 horticultural varieties. The dasheen, somewhat familiar to Americans, is a related species. Certain qualities enhance the value of taro plants over many other crops in tropical agriculture. The taro plant is adapted to wet or dry culture, grows rapidly in optimum conditions of soil and moisture, and produces two to four times the average yield of potatoes. Harvesting in both wet and dry fields is done by hand-pulling.

* Also named *Colocasia antiquorum* var. *esculentum* Schott.

The tuber is ovoid or obovoid, somewhat hairy, and at short intervals is encircled with rings, between which here and there is borne an occasional eye or bud (Fig. 8). The flesh of the tuber is like that of the potato, only more cheesy in consistency, and white generally speaking, though often creamy, tinged with yellow, rose or purple. In the Chinese food shops two kinds of tubers appear, large ones which function as corms and support the main plant and small ones which grow out at the side as lateral appendages.

Tubers may be steamed, boiled or baked; they may also be preserved in salt and dried for future use. Tests show that the corm is a high energy-producing food containing about 30% starch and 3% sugar. The moisture content is 61%, the protein a little over 1%, with a trace of fat and crude fiber. The ash produced is alkaline. When eaten in quantity, taro is a good source of highly assimilable calcium and phosphorus. It is similar to white potatoes in vitamin content except for thiamin, of which taro is a greater source. The leaves and petioles when cooked are excellent sources of vitamin A and a good source of vitamin C.

In Hawaii a fermented paste called " poi " is made from the pounded steamed corms. By addition of water, the consistency of poi is controlled; either a thin paste of " two-finger " consistency or a thick paste of only " one-finger " consistency is made. Dried taro products are flour and breakfast grits. It is interesting to note that taro which makes the best poi also makes the best flour. Taro bread containing 15% taro flour and 85% wheat flour stays fresher than ordinary bread because of the moisture-absorbing properties of taro. Cakes, cookies and doughnuts taste better when made with this flour. Taro flour makes

FIG. 8 (*Upper*). Taro tubers from the Chinese food shops.
FIG. 9 (*Lower*). Chinese arrowhead tubers.

excellent thickening for gravies and puddings because it does not contain the glutinous properties of wheat and become rubbery as consequence. Modern exploitation of the taro began in 1937 when the Hawaiian Taro Products Ltd. started operating. The company produced flour (Poyo-Meal), beverage powders (Taro-Lactin), a flour-skim milk infant food, and Taro-Malt, or Poyo-Malt, a plain or chocolate-flavored malt beverage powder.

Certain medicinal virtues are ascribed to taro. Seeds, though never observed in cultivated forms, are cited in Chinese literature as being slightly poisonous. A decoction of seeds, leaves or stalks may be used as an application in insect bites and other poisons. Taro-Lactin is now a regularly prescribed infant food, and patients suffering from ulcers and other alimentary disorders, or convalescents, derive great benefits from this easily digested nutritive food. It is also recommended strongly in pre-natal diets as well as for nursing mothers. Taro flour is prescribed to cereal allergy sufferers.

FIG. 10. Tubers of *Sagittaria latifolia* Willd., the North American arrowhead.

Chinese Arrowhead. In the Chinese food shops of New York two kinds of arrowhead tubers are sold; one is a native of China and is botanically a variety of *Sagittaria sagittifolia* L.; the other is *S. latifolia* Willd. which the Chinese have come to know only since they have been in America. The North American species was found by the Lewis and Clark expedition in 1804 to be the food mainstay of the Chinook Indians of Oregon, and in 1852 Perry noted this plant in the diet of the Chippewas. The Chinese arrowhead tuber is cooked and eaten in the same way as the taro. At Foochow it is planted like taro in the

spring and the tubers are harvested in October. Each plant produces four to six tubers. The tender stalk is also occasionally used for food. In Japan the arrowhead is cultivated as a food plant.

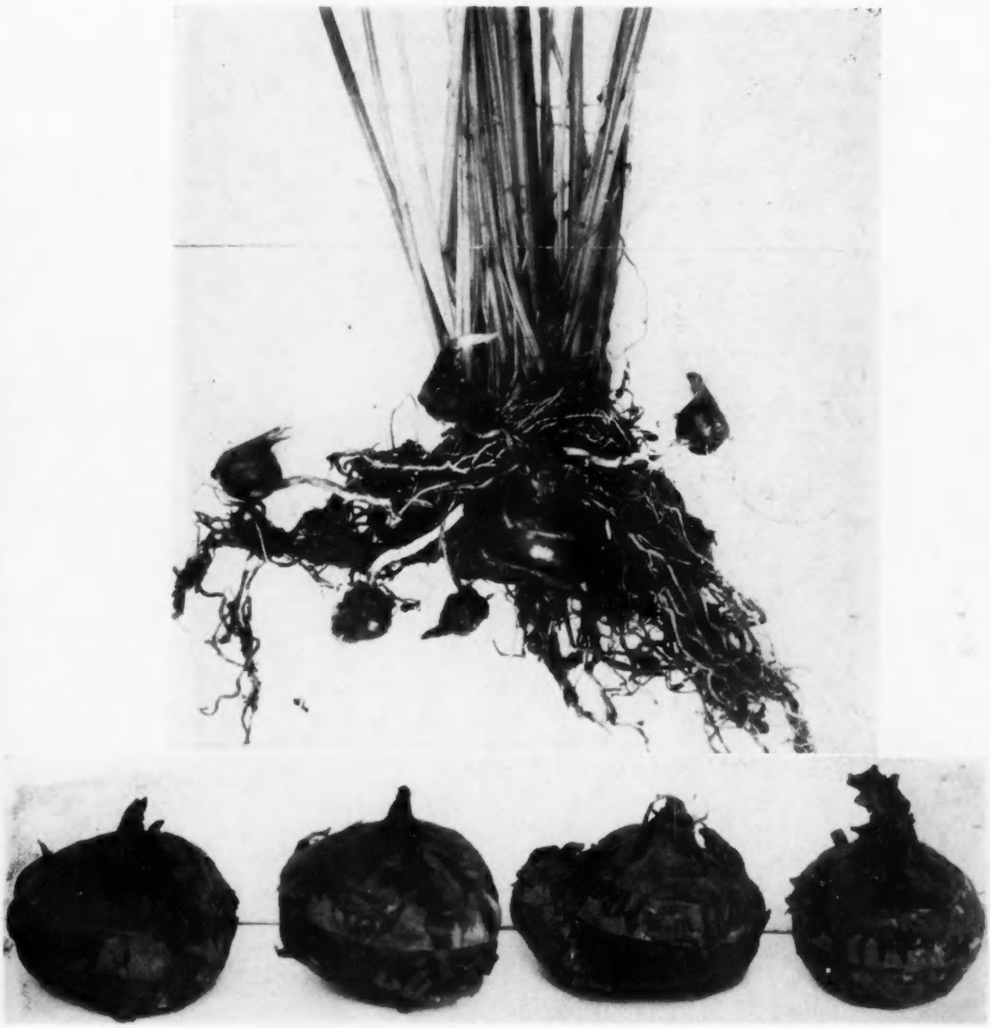


FIG. 11. Basal section and corms of Chinese water chestnut.

The name " arrowhead " comes from the arrow-shaped leaves held up by long petioles above the surface of shallow stagnant pools in which the plant grows. The leaves of the North American arrowhead have divergent basal lobes, while those of the Chinese species are broader and have less divergent basal lobes. An interesting observation has been made concerning the relation of root growth to leaf expansion in this plant. The first leaves are always narrow ovate-lanceolate, and each succeeding one is broader until sagittate lobes are developed and the leaf reaches its mature dimensions. Keeping the roots trimmed back when the plant is young checks leaf expansion

so that the leaves do not become sagittate. Trimming the roots after the plant has started to produce sagittate leaves, however, has no effect; sagittate leaves are produced continuously but they are smaller.

The Chinese arrowhead tuber (T'zu-ku) in shape resembles a small dark colored flattish onion about two inches in diameter and a little more than an inch in height (Fig. 9). A shoot projects from the center, and two lines encircle the tuber, indicating the scars of the sheathing leaves. The North American tuber (*S. latifolia*), on the other hand, is laterally compressed, has a terminal sprout at one end and two to four leaf scars (Fig. 10). Flowers are borne in whorls clustered about a scape that comes up directly from the rootstock. The flowers are imperfect and dichogamy is highly advanced. The seed of the arrowhead has not been described.

Propagation is by tubers and so readily takes place that compact masses of these plants spread over wide areas of water surface unless uprooted periodically. The projecting sprout develops a terminal bud from which roots and leaves emerge to form an independent plant. This in turn develops runners, at the ends of which new plants appear. The axillary buds on the old tuber may produce new shoots that will develop a new plant system or may decay, leaving its offshoot independent.

The raw tuber of the arrowhead exudes a milky juice, and its flesh is like that of a potato and serves as a source of starch. When boiled it becomes sweet and acquires a farinaceous taste. The nitrogenous elements are *a*) an albuminoid, soluble and caseinlike; *b*) a soluble albumen coagulating at 74° C.; *c*) a small amount of a non-albuminoid; and *d*) varying amounts of non-albuminoids, of which asparagin is an important constituent. The tubers are reported to be without vitamin content and the fuel value is 94 calories per 100 gm.

Analysis of fresh tubers shows them to have the following composition:

	***Sagittaria sagittifolia* L. var. *sinensis* (Sims) Makino**	***Sagittaria latifolia* Willd.**
Water	61.51	68.88
Protein:	7.00	4.44
Albuminoids	4.71	3.98
Amides (by difference)	2.29	0.46
Fat	0.24	0.76
Starch	22.95	19.69
Cane sugar	*2.26	2.49
Pentosans	0.32	...
Crude fiber	0.72	0.98
Ash	1.69	2.04
Undetermined	3.31	2.71

*** Sample contained no reducing sugars.**

The arrowhead has many therapeutic uses in China. Bruised leaves are applied to infected sores, snake and insect bites, and as a powder to itching diseases. Eating raw tubers is said to be dangerous, producing fluxes and hemorrhoids and inducing premature birth.

Chinese Water Chestnut. The name " water chestnut " is applied to both the fruits of the genus *Trapa*, described later, and to the flattish corm of a sedge, *Scirpus tuberosus* Roxb. (Fig. 11), which is not in any way related to *Trapa*. We are here concerned with the sedge corm, and among the Chinese names applied to it, the one commonly used is " Ma-hai ". In the markets the corm is dark reddish-brown and is about an inch and

a half in diameter. The meat, which is succulent like that of an apple, is of uniform consistency, and the taste resembles that of sweet corn. They may be eaten raw or cooked. These along with bamboo shoots and other Chinese vegetables are cooked and served with meals in the homes of foreigners in China. Pared and impaled on thin bamboo sticks, they are sold by street vendors and eaten raw almost as a confection. Sliced water chestnuts are one of the ingredients of chop suey in the United States, and shredded they often appear in meat and fish dishes. Americans who take the trouble to shop in the Chinese markets have found them delectable in salads and soups.

The Chinese water chestnut is about 77% water. The cane-sugar content in water-free samples averages about 27.5%, while protein is rather low. The starch content is between 7% and 8% in the fresh corm.

The plant which produces the corms which in turn produce new plants, grows in stagnant water and sends up cylindrical hollow leaves which project above the water level. Runners grow radially from the top of the old corm at the base of these leaves and on the end of each develops a young corm which at maturity is disconnected from the old plant and planted separately.

It is said that the Chinese water chestnut also possesses medicinal virtue. For example, when children accidentally swallow coins, water chestnuts are immediately given to them in quantities, either raw or boiled, and are claimed to decompose the metal.

Chinese Ginger. The much-branched finger-like rhizomes of ginger displayed for sale in New York Chinese food shops are the source of confections, condiments, essences and medicines used by the Chinese (Fig. 12). In the United States candied ginger, powdered ginger, ginger ale and preserved ginger are well

FIG. 12. Rhizome of Chinese ginger.

known. The plant producing these rhizomes is thought to be of Asiatic origin and is preferred to the West Indian variety because it is more succulent. There was some confusion at first in the identification of Chinese ginger, but it was finally determined to be *Zingiber officinale* Roscoe.

From the alluvial lands of the Canton delta where it is extensively cultivated, much of the ginger is exported as preserved ginger. It is cultivated as far north as Shantung province and is called by the Chinese, "Chiang". The plant was formerly believed not to flower, but eventually flowers were found. The inflorescence is dense and cone-like. No seed has ever been reported. The leaves when crushed are highly aromatic and even under normal conditions give off an odor. Volatile substances emanate from the rhizome which burn the hands if they are not covered. Ginger root, though easy to grow, is nowhere grown in the United States on a commercial scale. Propagation is by division of the rhizome.

According to a Chinese Materia

Medica, fresh ginger stimulates the digestive organs, quiets nausea, checks coughs and acts as a carminative and astringent remedy in dysentery. It is considered an antidote for mushroom poisoning. The ginger skin is used to clear opacity of the cornea, and the juice from the leaves is drunk as a digestive stimulant and as a local application in ecchymosis. Oil of ginger is used as a condiment. Essence of ginger, Chiang-lu, is considered to be antiseptic, antimalarial and expectorant. A tincture is used as a stimulant in colds and indigestion.

Analyses show that the rhizome contains 3.7% of fatty oil, 1.35% of essential oil, and some gingerol and resin.

FIG. 13. Candied Chinese ginger.

Shoots and Greens

Bamboo Shoots. Bamboo shoots, one of the ingredients of American-Chinese dishes in the United States, are really the swollen buds of bamboo canes (culms) before they have fully emerged from the ground. They originate at the joints (nodes) of the horizontal underground stem (rhizome) of the running type of bamboo (polypodial) or from a basal node of an old cane of the clump-forming type (sympodial). The shoots are severed in their very young stages from the mother plant in the spring and dug up. Fresh shoots sold in the native Chinese markets are conical in shape and covered with tough, leathery, overlapping, sheathing leaves which protect the tender shoot and provide a smooth casing against rough soil particles as it forces its way up through the ground.

Proverb and saying are inextricably mixed with the ancient customs applied to bamboo cultivation. In regard to the time when bamboos produce their shoots, there is a saying in India that bamboos will not put up their shoots until the thunder comes. Kurz cites an incident

told by a certain Captain W. H. Sleeman. During the rains of 1835 the captain discovered that his bamboos at Jubbalpore had not produced their shoots at what he considered the usual time, so he asked his gardener the cause. The gardener replied, " We have had no thunder yet; as soon as the thunder comes you will get shoots ". The captain inquired what possible connection there could be between claps of thunder and the shooting of bamboos. " God only knows ", said the gardener, " but we know that until the thunder comes, the bamboos never shoot well ". The thunder came and the gardener's theory seemed confirmed, for the bamboos began and continued to produce abundant shoots.

It is the practice in some parts to cover bamboo shoots with baskets as they come through the soil, because exposure to light will make them fibrous and bitter. In general, an eight-year plantation should annually produce 40 pounds of shoots per mow (one-sixth of an acre).

In New York's Chinatown, among the representative array of Chinese vegetable foods, both dried and canned shoots are displayed (Figs. 14 and 15). In spite of the desire of restaurants in the United States for fresh bamboo shoots, a source large enough to assure a steady supply is not yet available in this country to meet the demand. Chekiang province, among other bamboo-producing centers of China, is noted for the production of dried bamboo shoots. Most of the inhabitants of the Tien-mu Shan district make their living by preparing dried bamboo shoots. The sources of the product are divided into three groups, the " early " shoots, the " rock " shoots, and the " red " shoots. After the fresh shoots are dug out of the ground, they are washed and stripped of their sheath-leaves; then they are boiled in a big kettle filled with salt water. After two hours boiling, the shoots are taken out of the kettle and placed in a closed chamber, where they are dried over a steady fire for about four hours. The partially dried shoots are then taken out of the oven and rolled between the hands, after which they are pounded flat with a hammer. The shoots may also be sliced lengthwise and dried. Once more they are put back in the oven and dried for about one and a half hours. When the drying process is finished, they are taken out, placed on a table and graded according to the degree of tenderness. The entire process lasts about two days. From 200 catties (266.66 pounds) only about 20 catties (26.6 pounds) are obtained because of the high water content.

Bamboo shoots are good food. The heart of a shoot is crisp and white, like that of a potato, but when cooked does not become mealy. They should be boiled in salted water about 30 minutes or more until tender. It is said that when Robert Fortune was in China, he was in the habit of eating bamboo shoots as a vegetable almost every day; foreigners in China today still use them as a regular table vegetable. Experimentally it has been proved that bamboo shoots contain vitamin C and have a fuel value of 185 calories per pound. An analysis shows their water content to be 90%; they also contain 3.2% protein, 0.2% fat, 6.2% carbohydrates, and 0.4% ash.

Among the species producing edible shoots, *Phyllostachys edulis* Carrière (*P. pubescens* H. de L.) is highly prized. It not only produces fine quality edible shoots but is one of the largest timber bamboos of eastern China and Japan. The story is told about Men Tsung, one of the 24 paragons of filial piety, that one day when his mother fell sick and craved soup made from young shoots of the bamboo, he went to a bamboo plantation to fetch some, but it was in the depth of winter when such things were not to be had. In his distress he wept so

FIG. 14 (*Upper*). Contents of can of preserved bamboo shoots.
FIG. 15 (*Lower*). Dried slices of bamboo shoots.

hard that the ground covered with his tears was softened, so that an abundance of young shoots sprang up and he was able to gather enough to bring home to his sick mother.

Bamboos include the only trees of the grass family, and because of the peculiar structure of their canes with hollow internodes, of their hardness, of the great tensile strength of their fibers, and of the ease with which they can be split into strips, they are among the most useful plants in the world. Not only is the plant itself with its network of underground stems a fine soil stabilizer, good for stream banks and hillsides in preventing erosion, but also it may be used as a hedge plant and for windbreaks. Houses, sheds, bridges, barracks, even temporary airplane hangars are made of bamboo, as well as all sorts of furniture, implements and handles, baskets, crates, chicken coops, fences, buckets, trays, screens, blinds, draperies, pipes, stakes, canes and poles. In World War II a sort of three-story basket scaffolding of bamboo was built over the roofs of public buildings in the war areas of China in order to detonate aerial bombs before they struck the buildings. Bamboo was one of the first sources of paper in China and today with improved techniques produces fine quality paper. A visit to the Metropolitan Museum of Art in New York City will show to what extent bamboo has been used in the manufacture of musical instruments, especially among primitive peoples. These are only a few of the uses to which bamboo is put but they serve as an indication of the possibilities. Not only are the canes and shoots used, but also the leaves. A decoction of them, according to Chinese medical lore, can be fermented and used to treat fevers and to clarify the intellect. Congee with bamboo leaf decoction is thirst-relieving and purifies the heart. One of the small varieties of bamboo has very large leaves, large enough that local shopkeepers can use them to wrap up small packages of confections. The tough sheath leaves of the shoots of *Phyllostachys edulis* are large enough to be used as material for the soles of sandals worn by coolies and farmers in the areas where they grow. Finally, bamboos are highly ornamental, and many varieties are grown for decorative purpose alone. Because of their grace as well as their versatility, they have figured greatly in the cultural progress of many Asiatic peoples, particularly of the Chinese and Japanese, and in their art have been given a place of distinction and symbolical significance.

Chinese Cabbage. Among the fresh leafy vegetables eaten by the Chinese and sold in Chinatown food shops, one of the most important is the Chinese cabbage. There are two kinds and they are sufficiently different that they are now referred to separate species, *Brassica chinensis* L. (Pak-choy) and *B. pe-tsai* Bailey (Pe-tsai). The two Chinese names are but two dialectic pronunciations for the same Chinese characters meaning " white vegetable ". The latter is more highly esteemed than the former and has been successfully introduced into the United States. It is sold in the American markets mostly under the name " Shantung cabbage ". This cabbage is an annual and is distinguished by its elongated loosely rolled head (much more compact in recently developed forms) and winged leaf petioles (Fig. 16). The former species, on the other hand, is a biennial plant, does not form a head, and its petioles are celery-like and marginless (Fig. 17). In the second year the plant develops a tuberous root not unlike a turnip in taste. Both cabbages are autumn vegetables and grow best in cool moist soil.

In order to keep the head of the pe-tsai cabbage compact and tender, its top should be tied together when nearly mature. The fresh head is prepared in the

same manner as ordinary cabbage and makes a very excellent table vegetable. It is milder and sweeter in taste than our domestic cabbage. The Chinese often serve it uncooked, shredded with sugar and vinegar. In the United States it is also eaten raw, sliced across its width in salads. Pe-tsai cabbage can be made into a good soup or puree which is easily digested by young infants.

The leaves of *B. chinensis* are spreading, like a turnip top, and are borne on long naked fleshy white stalks. These are the most edible portion and may be cooked and served in the manner of either cabbage or asparagus. The leaves are cooked and eaten as greens. In the Chinese markets the cabbages are sold as bundles of leaves or blanched petioles.

Analysis shows that the pe-tsai cabbage does not differ as regards food value from our cultivated cabbages; the water content is somewhat higher, but the protein content is somewhat lower. The pak-choy cabbage shows nearly the same composition except in the amount of reducing sugars; water-free material of pe-tsai amounts to about 30%, that of pak-choy only about 10%. Details are as follows:

	Brassica pe-tsai (Pe-tsai)		*Brassica chinensis* (Pak-choy)	
	Original	Water-free	Original	Water-free
Water	95.74	...	96.55	...
Protein:	1.19	28.07	0.78	21.96
Albuminoids	0.48	11.36	0.41	11.43
Amides (by difference)	0.71	16.71	0.37	10.53
Fat	0.15	3.57	0.10	2.82
Carbohydrates:	1.69	39.55	0.77	21.51
Starch	0.31	7.19	0.31	8.61
Cane sugar	0.09	2.11	0.09	2.45
Reducing sugar	1.29	30.25	0.37	10.45
Crude fiber	0.52	12.16	0.46	12.86
Ash	0.56	13.28	0.65	18.33
Undetermined	0.14	3.38	0.80	22.52

Pe-tsai contains a considerable amount of anti-scorbutic vitamin C and is a good source of vitamin B, is fair for vitamin A, but low in vitamin G. Pak-choy, on the other hand, is an excellent source of vitamin C, a good source also of both vitamin B and vitamin A, but fair only for vitamins D, E and G. Fresh leaves of *B. chinensis*, if pickled in salt for three days, lose 50% of their original vitamin B, but when pickled in a paste of salt and rice bran, the vitamin content is increased to almost four times the original value because of adsorption of water-soluble vitamin by the leaves.

Brassica chinensis is considered in Chinese medicine to be cooling and antivinous. Prolonged and excessive use is thought to be slightly deleterious, causing an itching eruption and retarding recovery from disease. Ginger is used as an antidote. Medicinal use is recommended in fevers and to quench the craving for wine. It is also considered to be laxative and diuretic. The seeds are used to arouse a " dead drunk ", and the expressed seed oil, when rubbed on the scalp, is thought to promote growth of hair.

Chinese Celery. The Chinese variety of celery, *Apium graveolens* L. (Ch'in Ts'ai), is slender and green (Fig. 18), not thick-stemmed and crisp like the American cultivated variety. It is a common vegetable with the Chinese.

FIG. 16 (*Left*). Head of pe-tsai cabbage.
FIG. 17 (*Right*). Head of pak-choy cabbage.

Sometimes they eat it raw, but they usually take it about half cooked, which is certainly a safeguard when the native manner of using fertilizer in the garden is considered.

The properties of Chinese celery are such that it is considered digestive, cooling, quieting, alterative and tonic. It is recommended in menstrual fluxes and in digestive troubles of children. The expressed juice of the stalk is the form much used medicinally. The food value is high, the vitamin content including vitamins A, B, C and D; it is a particularly good source of vitamin B. Its fuel value in calories per 100 gm. is 17. The general composition is:

Water	93.6	Carbohydrate	3.3
Protein	.5	Crude fiber	1.1
Fat	.4	Ash	1.2

Lily Bulbs and Flowers. Lilies, including both *Lilium* and *Hemerocallus*, are sources of food in China. Bulbs of the former are sold in Chinatown markets and are highly esteemed as a delicacy. *Lilium brownii* Poit. furnishes a large part of the bulbs used by the Chinese in San Francisco and elsewhere (Fig. 19). The bulbs of *L. tigrinum* Ker-Gawl., *L. cordifolium* Thunb., *L. bulbiferum* L. and other species are also used, both dry and fresh. One feature which recommends the lily bulb is the ease with which it is dried. The bulbs sold in the Chinese markets seem, according to one observer, to be nearly devoid of the bitter principle reported to occur in several species of *Lilium*. When boiled, they make a palatable food, but they can not be as cheaply cultivated as other comparable food plants, and furthermore the ornamental value of their flowers would prevent their extensive cultivation for use as food. In Japan a farinaceous food is derived from the

bulbs by first crushing them in wooden mortars and separating the starch from the cellular mass by repeated washing. The former is hung up in bags for winter use, while the latter is dried in round perforated cakes somewhat resembling miniature mill-stones and hung up to continue drying. Bulbs of the Chia-peh Ho (*L. tigrinum*), both cultivated and wild, when properly cooked are not at all bad eating.

The flowers of *Hemerocallus fulva* L. and *Lilium bulbiferum* L. also furnish food. Dried or fresh flowers of the former, the Chinese daylily, are sold in Chinese food shops under the names " Gum-tsoy " (golden vegetable) and " Gum-jum " (golden needles). They are used in soups and in meat dishes with noodles. The basal end of the dried flower is first removed and the rest is cut into several segments. Enough water is added to the flowers to insure soaking to a soft gelatinous mass which is then added to soups already cooked; the whole is then boiled. Lily flowers are also eaten as a vegetable, being a good source of vitamin A but only fair for B. Dried lily flowers formerly held a high place among exports from China.

An analysis of lily bulbs and flowers shows the following percentage content:

	Lilium brownii		*Lilium tigrinum*	*Hemerocallus fulva*
	Dried bulbs	Fresh bulbs	Fresh bulbs	Dried flowers
Water	10.16	66.72	71.46	18.13
Protein	5.57	2.33	4.51	9.33
Fat	0.37	0.59	0.24	2.45
Carbohydrate	65.49	21.90	21.60	60.49
Crude fiber	1.64	0.75	1.04	4.76
Ash	2.68	1.24	1.15	4.84
Undetermined	14.09	6.42	...	...

Bulbs of lilies are considered in Chinese medicine to be tonic, eliminant, carminative, quieting and expectorant. They are also used in epiphora, suppression of milk, post-partum neuroses, and externally in swellings and ulcers. The flowers are dried, powdered and mixed with oil for the treatment of moist eczema and vesicular eruptions in children. The bulblets in the axils of the leaves are steeped in wine and used in the treatment of intestinal disorders. Dried bulbs appear in commerce as " Pai-ho Kan ", while fresh bulbs are called " Hsien Pai-ho ". A sort of starch is also made out of the bulbs, which is known as " Pai-ho Fen ".

Fruits and Nuts

Chinese Date. Among the dried fruits stocked in Chinatown shops, usually in glass jars, is the Chinese date (Tsao), or jujube (Fig. 20). It is well known and is identified in the classics as one of the five principal fruits of China. Chinese dates are eaten fresh when they can be obtained; otherwise dried (like raisins or lychees), sugared, stewed or smoked. The taste is sweet, the meat firm, and when fresh the fruit is plump but has a wrinkled skin when dried. The color is dark red and the shape somewhat elongated or ovoid. Propagation is by seeds, but to insure true breeding of a variety, suckers from the base of the trees are planted.

The common species of jujube is *Zizyphus jujuba* Mill. which is a thorny tree-like shrub, but the one from which Chinese dates come is *Z. sativa* Gaertn. (*Z. vulgaris* Lam.) which inclines to thornlessness under cultivation. Most Chinese dates come from North China, particularly from Shantung province where

they are best. The trees produce not only good edible fruits but also fruit which may be used for fodder, for ornament, for gum lac production by lac insects, and for medicinal purposes. The bark, particularly the root bark, is a commercially unimportant source of tannin. The wood of old trees is sought for the manufacture of combs and for all sorts of turnery.

Analysis of the fruit pulp is:

	Original	Dried
Water	13.44	...
Protein	2.93	3.39
Fat	...	...
Carbohydrate (sugars)	55.25	63.83
Crude fiber	...	...
Ash	1.73	2.00
Undetermined	26.65	30.78

The carotene content has been determined at 0.70 mg./g. of fruit pulp, and there is also a fair amount of vitamin C.

Medicinally the fruits of wild jujube are considered cooling, anodyne and tonic. The kernels of the seeds are reported to have a sedative effect and are recommended to those who are subject to sleeplessness. If eaten frequently, they are said to increase the flesh and strength. The cultivated fruits are considered nourishing, beneficial and laxative. They are thought to be an antidote to aconite poisoning and are recommended in nausea and vomiting; also for abdominal pain in pregnancy. They are also used externally in poultices and applications on wounds. The leaves are regarded as a diaphoretic and are prescribed in the typhoid fever of children. A decoction of the heartwood is said to have a beneficial action on the blood. The root is used in fevers of children and to promote growth of hair. The bark is used in a decoction with mulberry bark as a wash for inflamed eyes.

Chinese Olive. The olive-like fruits sold in Chinese food shops are not the olives (*Olea europea* L.) known to American grocery stores, but are furnished by two species of *Canarium*. Those of *C. album* Raeusch. are called "white olives" (Paak-laam) (Fig. 21), those of *C. pimela* König, "black olives" (Oo-laam or Wu-lan). Both species, until found wild on the Island of Hainan, were known only in cultivation. It was in 1845 that Robert Fortune first saw in Foochow the so-called Laam-shue, or Chinese olive. Other Chinese names for them are "Kan-lan" and "Ching-kuo".

Fig. 18. Chinese celery.

Chinese olive trees are evergreen, resinous, develop a dense crown of spreading branches, and sometimes reach a height of 20 meters. The trunk is straight with whitish bark and light colored wood which is fairly common in the markets though expensive. Though native only to Hainan Island, the trees are now found cultivated all the way from Cochinchina to the province of Szechwan in China

proper, including Kwangtung and Fukien provinces.

The fruit of the white olive is dirty yellow and is much wrinkled when ripe. The seed tapers to a point at both ends, is angled along its length, and is slightly rough. The fruit of the Chinese black olive, on the other hand, is purplish black, smooth when ripe; and the seed is blunt and smooth. The fruits ripen September to November and are about an inch and a half long. The seed is one- to three-celled and has one to three kernels.

The Chinese olive is highly esteemed as a condiment or as a side dish, either fresh or salted. Pulp of the fresh fruit is somewhat acrid and disagreeable, and so requires special treatment to make it palatable. It is often added to wine to moderate or counteract its effect. Not only is the fruit pulp eaten but also the kernels of the seeds, preferably those of the black olive. When fresh, the latter taste like walnuts and in composition show great similarity to them. They are sold under the Cantonese name " Laam Yen ". A microscopic examination shows well formed aleurone grains and a yellow fatty oil which absorbs 83.17% of iodine.

The most important constituent of the fruit pulp is fat, which forms nearly one-fourth of the nutritive material. The ascorbic acid content in mg./g. of the edible portion determined by the iodine method is 0.15. The fuel value is 1150 calories per pound. Other details in the composition of *Canarium album* fruit are:

	Pulp		Seed	
	Original	Water-free	Original	Water-free
Water	73.22	...	5.71	...
Protein	0.77	2.86	16.44	17.44
Fat	6.55	24.46	59.57	63.18
Carbohydrate	5.64	21.94	0.92	0.97
Crude fiber	4.15	15.48	3.20	3.39
Ash	1.50	5.61	5.16	5.47
Undetermined	8.17	30.53	9.00	9.54

The fruits are medicinally characterized in Chinese medical lore as stomachic, sialagogue, antiphlogistic, alexapharmic, antivinous and astringent. The seeds, incinerated and reduced to powder, are thought to have the power of dissolving fish bones accidentally swallowed, and are used in treatment of fluxes and eruptive diseases of children. Bruised kernels are used as a poultice for cold sores or fever blisters. Such poultices appear in commerce as do also the leaves of *Canarium pimela*. Kernels of this species are stimulant, tonic, and have corrective properties.

Lychee. The lychee (*Litchi chinensis* Sonn.) (Fig. 22) is supreme among the fruits of South China, and the first contact which most Americans have with truly Chinese fruits is with it. Chinese laundries in most of our big cities proffer lychees at Chinese New Year to their regular customers as a courtesy, and they can be bought in quantity in New York's Chinatown.

The fruits are round or oval and the outer coat is thin, leathery, brick red and covered with short hard points, becoming brittle when dry. When dried, the fruit pericarp loses its bright red and becomes grayish. The pulp of the fresh fruit is white, jelly-like and juicy, and encloses a single smooth brown seed. The dried pulp is like that of a raisin.

FIG. 19. Lily bulbs sold in Chinese markets for food.

FIG. 20 (*Upper*). Dried Chinese dates, *Zizyphus sativa* Gaertn.
FIG. 21 (*Lower*). Preserved Chinese white olives, *Canarium album* Raeusch.

There are many varieties but not all of them can be eaten fresh. Those that can not can be preserved by drying or canning. Others are used in making lychee wine.

The trees are evergreen and may grow to a height of 50 feet. Besides bearing edible fruit they furnish wood which has considerable value for cabinet work and interior furnishing. Most of them are found growing on dikes along canals or between fields where their roots are good soil-binders and hence add to the protection of the fields from floods. The roots are often dug out for fuel, for which they are much esteemed because they burn with a hot almost smokeless flame. Finally, lychee trees are considered very ornamental.

Analysis and nutritive evaluation of the dried fruit show the carbohydrates to be a mixture of simple easily digested sugars. Vitamins A and B are lacking in both the dried and the fresh fruit. Fresh lychees, however, are a good source of vitamin C. Their composition is:

Water	84.83	Carbohydrate	13.31
Protein	0.69	Crude fiber	0.23
Fat	0.58	Ash	0.37

Chinese Horned Chestnut. A frequently seen plant food of Chinese origin is the buffalo-head fruit, or horn chestnut (*Trapa bicornis* L.). A water plant produces the nut which when ripe falls to the bottom of the pond where it remains all winter. Because of its curious shape, it is frequently found in other than food shops, American as well as Chinese. The name " buffalo head " was given the nut because of its resemblance to the head of a buffalo with its two large curved horns (Fig. 24). Another name is " water chestnut ", and its Chinese name is " Ling Ko ". Robert Fortune tells how women and boys float about in round boats resembling wooden wash tubs, and push their way among the masses of plants without hurting them, collecting the nuts as they go.

Two related species also produce edible nuts, *Trapa bispinosa* Roxb., the Singhara nut of Ceylon, with nuts having two straight slender barbed spines, and *Trapa natans* L., a native European species which bears nuts with four spines. The specific name *caltrops* has also been given to the four-spined species because of its resemblance to the bronze or iron balls with radially projecting spikes (called caltrops) thrown on the ground in ancient warfare to slow the advance of foot soldiers or a cavalry charge. The latter plant has spread and become established in the United States, in some instances growing in such dense floating masses of vegetation as to choke the water course. The fresh nuts are said to be good in salads.

The nuts of the Chinese horn chestnut are always boiled before they are sold. If eaten raw, they are supposed to be harmful to the digestive tract. Considering the filthy stagnant water in which they grow, it is no wonder that worms and intestinal disorders inevitably follow if the nuts are eaten raw. When boiled, the nuts are considered nutritious and beneficial. Early writers assert that they relieve thirst, reduce fever and are helpful in cases of sunstroke. The flowers and shells of the fruits can be used in making an astringent, from which dye for the beard is obtained.

The starchy content of the fruit of *Trapa bicornis* L. in its dry state is 67.5% with 12.1% protein, of which 11.6% are albuminoids.

Chinese Almond. Chinese almonds are seed kernels of several sweet varieties of apricot, *Prunus armeniaca* L. (Hsing-jen), which, because they are grown in the northern province of Hopei (formerly Chihli), have led to the mistaken impression that almonds occur in China. In certain sections of that country true almonds would undoubtedly grow well.

These varieties, propagated exclusively from their seeds, produce edible kernels

which taste like true almonds. The four principal "almond"-producing varieties bear the following types of fruit: *a*) a small red fruit containing large medium soft stone and sweet kernel, the best variety; *b*) a larger fruit, also of red, but with hard stone; *c*) a yellow-fleshed fruit with the same open tree habit as the preceding and also with hard stone; and *d*) a fruit with bitter seed kernel which in small quantities can be used to give flavor to confections and to make Chinese almond soup.

Almond cookies are served as dessert in Chinese restaurants in the United States; salted or blanched Chinese almonds are also good eating. A tasty gruel and compound almond flour are also made from Chinese almonds. A bitter apricot kernel is highly toxic because of the presence of prussic acid. The bitter toxic kind is smaller; the larger sweet kind weigh more than half as much again. The very large amount of oil in the kernels makes a fine emulsion when the kernels are rubbed with water.

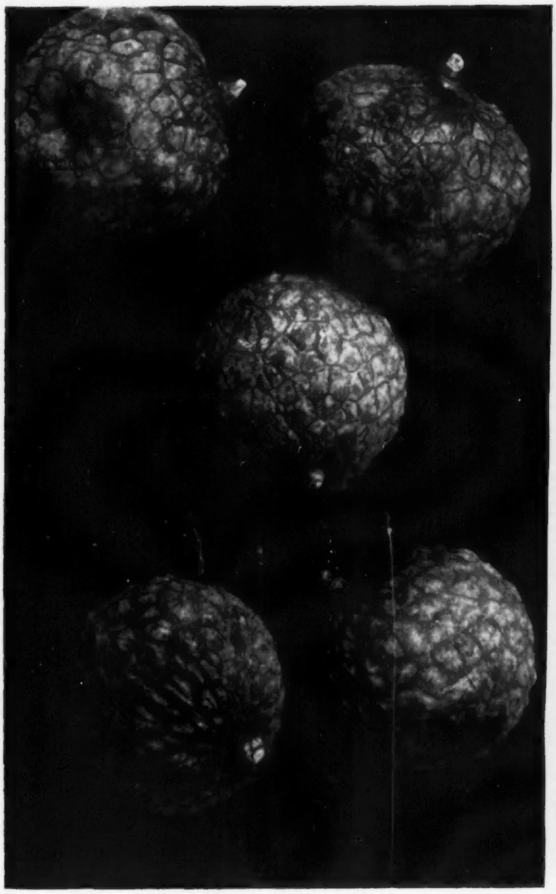


Fig. 22 (*Left*). Chinese lychees, *Litchi chinensis* Sonn.
Fig. 23 (*Right*). Skeleton of sponge gourd, *Luffa cylindrica* Roem.

Chinese almonds are a fair source of vitamin A and a very good source of vitamin B, but have no vitamin C. Their

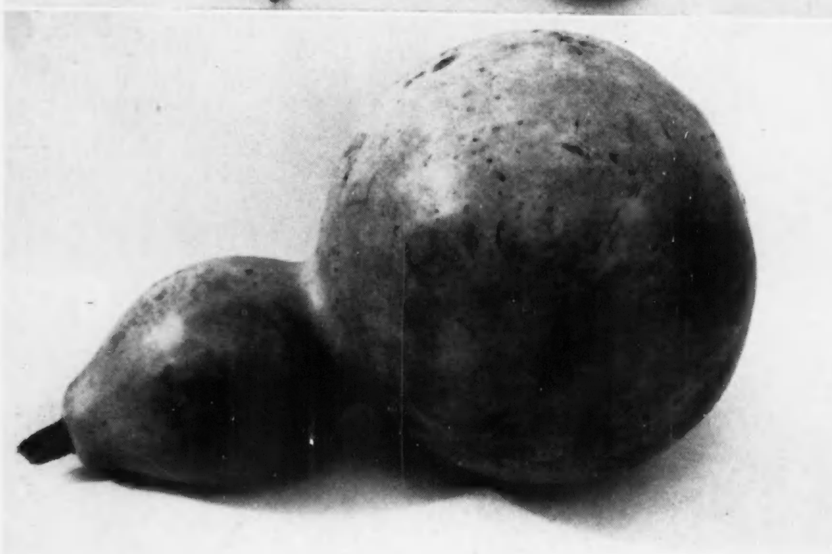


FIG. 24 (*Upper*). Chinese horned chestnuts, *Trapa bicornis* L.
FIG. 25 (*Lower*). The bottle gourd, *Lagenaria vulgaris* Ser.

calorific value is reported to be 606 calories per 100 grams. Fresh kernels of the sweet variety have the following composition:

Water	6.39	Carbohydrate	15.04
Protein	25.40	Crude fiber	2.97
Fat	47.30	Ash	2.90

In Chinese medicine the fruit of the bitter almond is considered to be useful in cases of heart disease. If eaten in excess, it is thought to harm the bones and muscles, to promote blindness and falling of the hair, " to benumb the mental faculties, and to injure parturient

women ". On the other hand, if dried and eaten, the fruit is thirst-relieving and antifebrile. The kernel is considered to be somewhat harmful, and it is said that a double kernel will kill a man. Sedative, antispasmodic, demulcent, pectoral, vulnerary and anthelmintic properties are ascribed to the kernels. Ginger and licorice are combined with them to form a confection used as a tussic and expectorant remedy. Another confection prepared by a process of fermentation is used as a prophylactic and tonic. A decoction made by crushing the blanched kernels in boiling water, with addition of other drugs and flavoring ingredients, is sold in the streets of some Chinese towns as a kind of tea used in coughs, asthma and catarrhal affections. The juice of apricot kernels are added to rice-congee and given in hemorrhages. Kernels are also crushed and made into a paste which is applied in cases of inflammation of the eye. Apricot flowers, besides being considered tonic, are used in cosmetic preparations.

Fig. 26 (*Left*). The Sing-kwa, *Luffa acutangula* Roxb.
Fig. 27 (*Right*). The leprosy gourd, *Momordica charantia* L.

Cucurbits

Chinese Luffa. Cucurbits of all shapes and sizes are sold in Chinese food shops, among them the luffas which are long cucumber-like fruits. There are two kinds. The commonest one in the markets of Chinatown, New York, is the Sing-kwa which is *Luffa acutangula* Roxb. (Fig. 26). It is longer than a cucumber, tapers at one end, is slightly curved at the pointed end, and has ten prominent ridges running its entire length. The leaves are rounded in outline and are only slightly lobed. The other gourd is *Luffa cylindrica* Roem., called by the Chinese "Sze-kwa", and by English-speaking people, "sponge gourd". This type is more often found in drug stores because of its special use as a sponge (Fig. 23). It has the same curved cylindrical form as the Sing-kwa, but it is smooth and has ten dark longitudinal lines instead of ribs. While it normally reaches one to two feet in length, it is said that some varieties in warmer countries may reach a length of nine feet.

The young fruits of both species, when not more than four inches in length, are peeled, boiled and served with butter, pepper and salt, or used as an ingredient in curries. The expressed juice of the leaves can be used as green dye for cloth. In Japan the young fruits of the Sze-kwa (*L. cylindrica*) are sliced and dried for future use as a vegetable.

Analysis of the fruits of the two species is presented in the following tabulation:

	Luffa acutangula		*Luffa cylindrica*	
	Original material	Water-free material	Original material	Water-free material
Water	94.90	...	94.66	...
Protein	0.68	13.39	0.51	9.57
Fat	0.24	4.70	0.19	3.72
Carbohydrate	1.03	39.84	3.31	61.99
Crude fiber	0.72	14.03	0.46	8.58
Ash	0.43	8.43	0.41	7.65
Undetermined	1.00	19.61	0.45	8.49

Further analysis shows that the fruit of Sing-kwa contains an amorphous bitter principle called "luffein" which acts as a purgative. Pressed cakes of this gourd are bitter and have a toxic reaction. The fruit of *L. cylindrica* (Sze-kwa) contains saponin and abundant mucous. Feeding tests show that the fruits of *L. cylindrica* are low in vitamin B. By the dye method they are shown to contain 122 international units of vitamin C.

The seeds of both species produce similar oil which is colorless, odorless and tasteless, and can be used as a substitute for olive oil. It contains 67.5% to 70.0% palmitic acid and 30.0% to 32.5% stearic acid; also some myristic acid as glycerides.

When the sponge gourd, or Sze-kwa, is mature, the pulp disappears and the vascular network, which is the skeleton of the fruit, hardens to form a dense mesh like that of a sponge. Because of its use in washing and drying, it is often called the "dish-cloth gourd". In addition to its use as a sponge, there are many other uses to which it is put, such as shock absorbers, table mats, slipper soles and packing material for fragile objects as well as for stuffing pillows, mattresses and saddles. Its insulating quality against heat gives it a special value in the manufacture of tropical

helmets. Matting, baskets, sandals and toys are made of it in combination with other materials. The uses reach even into the strategic class of materials, for they make excellent oil filters for steamships, and during the war the demand for them grew tremendously for use in outfitting naval vessels.

The ripe fruit of Sze-kwa, burned and pulverized, has a number of medicinal properties. The fiber also is esteemed as a medicine. The leaves even are used in skin diseases and orchitis, and the vine and root for decaying teeth, ozoena and parasitic infections.

Leprosy Gourd. Another cucurbit sold in Chinese markets is the leprosy gourd (*Momordica charantia* L.), or K'u-kwa (Fig. 27). The plant originally came from countries south of China, but has become domesticated in the southern provinces. They have been grown in Chinese vegetable gardens on Long Island.

The fruit is like a cucumber, six to seven inches in length, green, turning to yellow when ripe, and the skin is marked with longitudinal rows of oblong tubercles. When ripe it bursts open into three divisions, disclosing many rounded scarlet pulp masses, each containing in the center a flat seed curiously marked and tuberculated.

Only the young fruits are eaten; the old ones are used for medicine. The fruits themselves are not regarded so much as a source of food as of flavor which they impart to preparations; hence they are often placed in the class of condiments. The pulp is sweet and can be eaten, but mostly the fruits are used in salads, in pickles or as an ingredient of curries. The seed masses may be dried and mixed with meat, and are used in the preparation of appetizers. The fruit may also be fried with chicken or chopped and mingled with pork, or cooked with codfish. In India the fruit is sliced and then fried. It is necessary, however, to boil it in water first in order to remove all bitterness. One of its names, La-kwa, means " bitter squash ".

K'u-kwa is a fair source of vitamin A, an excellent source of vitamin B, and a good source of vitamin G. The fruit is considered to be cooling and strengthening. The seeds benefit the breath and invigorate the male principle (Yang).

Two-thirds of the nitrogenous constituents listed in the following analysis are albuminoid. Present also are considerable quantities of reducing sugars and true starch in relatively large amounts.

	Fresh fruits	Water-free material
Water	93.61	...
Protein:	1.18	18.48
Albuminoids	0.79	12.31
Amides (by difference)	0.39	6.18
Fat	0.20	3.19
Carbohydrates:	1.33	20.66
Starch	0.67	10.56
Cane sugar	0.06	0.74
Reducing sugar	0.60	9.36
Crude fiber	1.07	16.72
Ash	0.34	5.25
Undetermined	2.28	35.69

Bottle Gourd. Another gourd sold for food in Chinatown markets is the bottle gourd (*Lagenaria vulgaris* Ser.) (Hu-lu), which is probably better known for its

practical uses than for its food value (Fig. 25). Only young fruits are sold because it is in that stage that they are best eaten. The bottle gourd is a double-bellied gourd, which in outline resembles figure eight; it represents one of three forms of fruit produced by varieties of this species. The three forms are the club-shaped gourd, the pear-shaped gourd or calabash, and the bottle gourd. They are cultivated in central and northern China and in Manchuria. They will also grow in the New York area.

Because they develop a hard shell, the fruits are used for many purposes beside food. Small varieties showing stripes and particolored patterns are grown for ornaments. The young seeds, young leaves and pulp are eaten as food, but the shells of mature specimens are used to make dishes, scoops, vessels to hold different kinds of liquids, beggars' collection boxes, musical instruments, drug bottles, floats and the like.

Seeds of the bottle gourd are boiled in salt water and eaten when cold as an appetizer by the rural classes in China. Pulp of the fresh fruit is sometimes eaten like squash, but if eaten in too great quantities is liable to cause vomiting and purging. Stripped and dried pulp, when boiled with water, soy, sugar, etc., is an article of food called "Kampio" and can be preserved as such for a long time if sealed. In the past the Japanese have been making Kampio and exporting it exclusively to China as a regular business.

The pulp of *L. vulgaris* has low calorific value, is a good source of vitamin B, but is only fair for vitamins C and G. Is is considered to be cooling, diuretic and antilithic. The prickly cortex of the vine and the flowers are regarded as counterpoisons. Composition of the fresh fruit is as follows:

Water	94.50	**Carbohydrate**	3.33
Protein	0.64	**Crude fiber**	1.06
Fat	0.90	**Ash**	0.38

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Minor Oil-Producing Crops of the United States[1]

The pits and nuts of almond, Persian walnut, pecan, filbert, tung, apricot, prune, peach, cherry and plum; the fruit pulp of avocado and olive; and the seeds of citrus fruits, grape, apple, pear, cranberry and numerous other domestically cultivated plants are sources of valuable oils already in use.

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Introduction

In the six years since the author and G. R. Van Atta published an article under the present title,[2] new developments in the processing of minor oil-bearing materials, derivable principally from agricultural waste, have made it desirable to review the subject and include revisions in the data, descriptive matter on present practices and trends, and reports of technological investigations in the more recent literature.

However unstable may be our present scale of prices, the existence of enormous tonnages of agricultural wastes that pollute streams, create health hazards and are a liability to the food manufacturer suggests with some insistence that something be done to reclaim at least a part of their values. The observer, speculating on what he can recover or make from such wastes, would probably consider one or more items in the following list:

Feed	Plastic filler
Substrates for microbiological processes	Tannin
	Mucilage
Syrups	Pectin
Vegetable oil and meal	Furfural
Citric, tartaric, or other organic acid	Charcoal
	Fertilizer
Vitamins	

He may then attempt to sample a waste and have assays made to learn how much useful material he might recover and, with the data, estimate his gross returns per unit of weight. At this stage disillusion often comes, as he multiplies a number of conversion factors and ends with a pitifully small percentage of starting material in the form of salable goods. The vegetable oils in waste often hold more promise than some others in the list, as they usually involve mere segregation of the oil-bearing part, such as seeds, followed by expression or extraction, but even in this case the various economic factors bearing on a proposed enterprise should be carefully considered before a decision is made to set up a plant. In no instance has it been possible to process a single waste product for oil and obtain a fair return on the investment without the support of other salable merchandise, such as feedstuffs or fertilizers. Minor oils are usually recovered in plants capable of handling a variety of materials or in which oil extraction is only incidental to other operations.

The geographic location of processing

[1] Reprinted, with minor editorial changes and omissions, from Jour. Am. Oil Chemists Society **26: 65**. 1949. The excellent bibliography of about **400** citations has also been omitted.

[2] Oil and Soap **19: 119–125**. 1942.

plants for waste, with respect to the supply, is exceedingly important, because haulage costs (often on a high-moisture-content material) are frequently a deciding factor between profit and loss. The amount of raw material that is obtainable at centralized locations and can be counted on from year to year, is important, as well as the costs of separating and drying (if necessary) the fractions bearing oil. Then there is the problem of properly storing bulk quantities of materials with a minimum of decomposition, which is sometimes difficult to solve. The size of the oil plant itself should be given serious thought. A plant too small is uneconomical because of excessive labor costs, and a large plant is equally bad if a given waste, obtainable in the radius of economic haulage, is only sufficient for short-time operation, unless the same equipment can be utilized for recovery of other oils. Solvent extraction *vs.* expression must be evaluated in terms of type of material under consideration. Low-oil-content, highly abrasive substances like rice bran can not be handled to best advantage in either screw or hydraulic presses. For solvent extraction, an investigation of the various types of manufactured units should be made.

The prospective processor of oil-bearing materials, in computing probable returns from his products, must be concerned with quality and feeding value of his press cake and by-products of his operations. The Feed Control Laboratory, State of California Bureau of Field Crops, Sacramento, has issued a table of analyses covering a number of minor feed materials, including grape pomace meal, grape pulp and seed, mustard oil cake meal, olive oil cake meal, prune pits, almond hulls, avocado seed cake meal, tomato pomace, walnut oil meal, rice huller bran, rice polish, rice hulls, raisin oil cake meal, almond hulls, date pits, orange and other meals, in addition to the more common feedstuffs. Analytical data for protein, fat, fiber and ash are given in each case.

It is possible under prevailing prices to realize a substantial profit from certain oil-bearing wastes that were unattractive raw materials in pre-war years. Grape and tomato pomaces are cases in point. These wastes are nuisances which manufacturers are glad to dispose of at little or no cost, and, when converted to oils and feed, they return a profit in spite of high labor and processing charges and solve a serious disposal problem.

The sources of minor oils to be considered in this paper are not only those derivable from the wastes which accumulate at canneries, wineries and drying yards but also seeds and fruits that under favorable economic conditions may be grown and processed for oil. In this category we find olives, avocados, sunflower, safflower, rape and castor. The latter group may be considered potential oil crops of considerable bulk, but thus far they have been of only minor importance in our fats and oils economy.

Pit and Nut Oils

The pit oils of apricot, peach, prune and plum bear a striking resemblance to each other in composition and indeed are not readily differentiated. Cherry pit oil is reported to have a somewhat higher iodine number. These oils are like sweet almond oil, for which they are often substituted. If the pits are processed promptly after removal from the fruit, little or no benzaldehyde will be liberated into the oil by hydrolysis of amygdalin. The pit oils command a premium price over the commoner vegetable oils and are usually handled by essential-oil brokers.

Olive, date and avocado pits are not discussed in this paper. In the pressing of olives for oil the whole fruit, including pit, is crushed. Date pits from the

quantity of fruit that is currently pitted would yield a negligible volume of oil, and avocado pits contain less than 2.5% of ether extract on the dry basis. In the canning of pitted olives the pits are a waste product for which it would be desirable to find an outlet. The oil content of 3.5 to 7.0% is probably too low for profitable recovery. Inclusion in animal feeds has been suggested, but such a material, unless well ground, would undoubtedly contain hard sharp particles which might cause injury to the digestive tract.

Tree nuts, although rich sources of oil, must be considered primarily as luxury food items, and edible grades can not therefore be pressed economically except to fill small demands for specialty oils. Shelling plants, however, reject large amounts of moldy and inedible meats which are entirely suitable for oil recovery. The shells contain a considerable percentage of unseparated meats which are reclaimed by reducing the shell in hammer mills and subsequent screening.

Although tung nuts are not ordinarily classed with fruit pits and certainly not with edible tree nuts, they are included in this section because they bear a resemblance to both. The development of an industry from domestically grown nuts is still in its early stages, but crops are increasing as new acreage comes into bearing. Between the years 1936 and 1940 new plantings raised the acreage of tung orchards from 75,000 to more than 175,000.

Reported percentage composition figures for fruit pits and tree nuts, as well as characteristics of the oil in each, are included in Table I.

TABLE I

PIT AND NUT OILS

Kind	Pit in Fruit	Kernel in Pit	Oil in Kernel	Characteristics of Oil				
				I.V.	Composition of Fatty Acids			Unsaponifiables
					Oleic Acid	Linoleic Acid	Sat. Acids	
	Percent	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*	*Percent*
Apricot	5.6	20-25	40-47.4	100-108.7	63.3	31.1	3.7	0.7
Cherry	12-15	28	32-40	92.8-122	49.0	42.0	8.1	0.3-0.7
Peach	7.5-12	5-8	40-45.8	96-110	57.5-62.5	15.7-20.9	..	..
Plum	2.3-6	5-26.7	30-42.9	100-105	72.0	22	6	0.4
Prune	12.5	21	33-41.5	..	..	..	..	..
Almond	..	33-70	48.9-60	95-107	77	17.3-19.9	3.1-5.7	..
Filbert	..	40-48	50-60	84-90	78.2-88.1	2.87-9.1	4.9-8.0	0.3-0.55
Pecan	..	47-60	70-75	100-106	70.9-77.8	15.8-25.2	4-5.1	0.4
Persian Walnut	..	27-42	60-70	132-161.7	17.6	73.0 Linolenic, 3.2	5.3	0.5
Tung	about 50 (air-dry basis)	63.8-67	40-62.7	160-170	3.9-16.4	0.6-9.7 Elaeostearic, 74.5-86.3	2.6-8.9	0.4-0.8

Almond. Comparatively little almond oil has been produced in this country. One company in the Los Angeles area is pressing and marketing specialty oils at this time, including small amounts of almond oil. When the shelled nuts, which contain about 50% of oil, are dried, coarsely ground and cold pressed, about 75% of the oil is removed at 450 pounds of pressure. The oil is low enough in free fatty acids to be refined to a high-grade salable product by the

use of bleaching agents alone. American almond oil has an iodine value of about 103, which is slightly higher than U.S.P. specifications; nevertheless it is commonly accepted by the trade.

The meal, containing about 20% of oil, is edible but slightly bitter because of the skins. It is ground, sieved to various sizes and sold to the cosmetic and baking industries.

Commercial production of almonds in the United States is confined to California. Their production is a major industry in certain sections of the State, although the total crop represents only about 8 or 9% of the world crop. From the standpoint of acreage almonds rank third among the deciduous tree fruits and nuts of California, being exceeded only by prunes and walnuts. About 95,000 acres are in bearing at present, and recent plantings will increase this acreage within a few years. Although the market has thus far easily absorbed the entire crop, which has amounted to as much as 23,800 tons (1944 crop) in recent years, the industry is conscious of the possibility of surpluses, particularly in view of the increasingly large amounts of Spanish nuts being imported, and is seeking to find possible new outlets for its product. In 1944 imported almonds amounted to 37,500 tons, a figure in excess of any prewar imports.

High market prices make it difficult to devote first-grade nuts to oil production. In shelling and grading plants, however, a noteworthy amount of shriveled, resinous or otherwise inedible meats is rejected and could be used for oil recovery. There is also a noteworthy quantity of bitter almonds, brought in by growers from trees planted many years ago because of their supposed value in pollinating sweet varieties. Such almonds find little use except as seed for root stocks. In experiments conducted at the Western Regional Research Laboratory the fixed oil from the bitter almonds was found to have a bitter flavor and odor but could be rendered quite bland by ordinary methods of deodorization.

About 60% of the almond industry of California is represented by one cooperative. Approximately two-thirds of the annual U. S. almond crop is shelled. Nearly 10% of the meats, which amount to nearly 650 tons, are moldy, shriveled or otherwise inedible and contain 40% of oil, which means that about 260 tons of oil is annually available from this source. The present price quotation on almond oil ($.80 to $1.10 per lb.) is considerably less than in prewar years as a result of competition with imported almond oil.

Persian Walnut. The amount of walnut oil produced in this country is 300 to 600 tons annually. Raw material for oil pressing is divided between inedible meats rejected during shelling and meat fragments recovered from shell. The former have a slightly lower oil content (55.6%) than edible meats. One plant in Los Angeles produces most of the walnut oil manufactured and obtains its raw material principally from the shelling plant of a large cooperative. Screw-press equipment is used. The shell is reduced to flours of various screen sizes, which are sold as soft grit for blasting of metals, plastic filler, an ingredient of non-skid paints, and as a carrier for agricultural insecticides.

Walnut oil is similar to linseed oil and before the war was sold entirely to the coating industry. During and after the war it has been consumed as a specialty food oil. The outlet for walnut press cake, which contains a considerable amount of shell, is mainly the fertilizer industry, although some was used for stock feed a few years ago.

About 90% of the English or Persian walnuts grown in the United States are produced in California; the other 10%

are raised in Oregon. The California crop is divided about equally between northern and southern counties. The majority of the growers are members of an association which manages the disposal of the crop.

Production of walnuts in the United States for the period 1939–44, inclusive, averaged 63,350 tons, of which about 23,000 tons, or over 36%, were shelled. In years preceding the war when supply exceeded demand, some edible-grade nuts were pressed for oil, but current production is entirely from rejected meats.*

Pecan. Pecans are grown in a number of southern States, but principally in Georgia, Oklahoma and Texas, which account for about two-thirds of the national crop (61,000 tons, 1941–45 average). About 300 tons of pecan oil have been produced annually for the past two or three years. As in the case of walnuts, the source material is the discarded meats from shelling plants, which are shipped to a central point for processing. The oil is hydraulically pressed. It has been found fairly high in free fatty acids (8–12%), and some difficulties were experienced at first in refining it, but these have been overcome. The oil has brought from 40 to 50¢ a pound. Press cake is treated to recover tannin, of which it contains about 14%, and the residue is sold for stock feed.

Filbert. Commercial raising of filberts is almost wholly confined to Washington and Oregon. The crop for the five-year period, 1941–45, averaged less than 6,000 tons. Filbert oil is similar to olive oil, having a content in combined oleic acid of 85%, but the amount of inedible meats rejected from shellers would be so small that recovery of significant amounts of the oil would not be practicable unless the acreage devoted to the raising of the nuts were considerably expanded. One cooperative agency has a membership of about 3,500 producers who grow about two-thirds of the filberts and 70% of the walnuts raised in the Pacific Northwest.

Tung Nuts. Commercial production of tung, or China wood, oil from domestic nuts is a relatively new industry in this country. The first oil mill was established in 1928, but the crop at that time was small and supplied only a minor fraction of our requirements of this valuable drying oil. Most of our needs were met by imports from China directly or indirectly. In 1939 the entire domestic crop of nuts was 1,160 tons, representing about 230 tons of oil, but during the war years, when foreign supplies were almost completely cut off, the crop increased many-fold from new acreages coming into bearing and averaged 25,410 tons for the period 1941–46. The price per ton since 1940 has almost doubled, reaching a record high of $102 in 1944. The 1946 crop of 57,400 tons, or the equivalent of almost 12,000 tons of oil, was the largest on record. Production figures are estimated in terms of air-dried nuts in the husk.

The producing area for tung trees occupies a belt roughly 100 miles wide extending along the Gulf of Mexico from central Florida through Georgia, Mississippi, Alabama and Louisiana into southeastern Texas. Up to the present, Mississippi is the most important producing State, representing about two-thirds of the total annual production.

The important characteristic of tung oil is its high content in combined elaeostearic acid which contains three double bonds in conjugated relationship and contributes the unique drying characteristics of this oil. Tung oil is obtained principally by expression methods. The press-cake is poisonous to cattle and is suitable only for fertilizer.

* The year 1950 was an exception; surplus walnuts and almonds were both processed, the walnut oil being sold to the paint trade, the almond oil to pharmaceutical firms.

Apricot Pits. Nearly all of the apricot industry is located in certain well defined areas of California, such as the Sacramento, Santa Clara and San Joaquin Valleys, and a few of the southern counties. Washington and Utah also raise apricots commercially, but their combined crop is less than 11% of the national total. The average crop for the five-year period, 1941–45, was about 219,000 tons, of which more than 80% was dried, canned or otherwise processed. Many of the larger growers dry their own fruit and are able to sell the pits at prices as high as $55 per ton. At least four plants in California shell apricot pits to recover kernels, for which there is a strong domestic market. Current prices are 21–23¢ a pound. The dry-pit equivalent for processed apricots in this country is about 10,000 tons, which would yield about 2,500 tons of kernels. In the cracking process a considerable amount of broken kernels result, which are used to recover oil. The annual production of apricot pit oil is about 100 tons a year. The oil has always sold for a high premium price, is now listed at 65–85¢ a pound, and is used in the cosmetic and pharmaceutical industries as a substitute for sweet almond oil.

To recover apricot kernels and oil, the pits are first air dried, then cracked between steel rolls; then the mixture of shell and kernels is introduced into a brine tank of such density that the shells sink and the kernels float. The kernels are skimmed off, washed, dried and sorted. The whole kernels are ultimately used in making bakery goods, such as macaroon paste, after the amygdalin is hydrolyzed and large portions of the benzaldehyde and hydrogen cyanide are driven off. Apricot pit oil is recovered in screw-press or solvent extraction equipment. It is easily refined and bleached to a very pale product.

Prune Pits. No prune-pit oil is produced at present, although small amounts have been pressed in years past. It is similar to apricot- and peach-pit oils. The prune industry differs from the apricot industry in that the bulk of the crop is dried without removal of the pits. Some prune products other than the dried fruit are now sold, but these are of small volume. About 80% of the national prune crop (594,000 tons, 1941–45 average) is raised in California, the remainder coming principally from Washington, Oregon and Idaho. Over 90% of the total production is dried, canned or otherwise processed. Oil from the pits of all the prunes processed would amount to more than 5,000 tons, but it is useless to consider prune pits as a source of oil unless present marketing practices were to change in favor of pitted prunes. Agnes Fay Morgan of the Home Economics Division, University of California, College of Agriculture, found that prune pit oil is relatively rich in vitamins A and E.

Peach Pits. Growing of peaches is a widely distributed industry. Leading States in this respect are New York, Pennsylvania, Michigan, Virginia, South Carolina, Georgia, Washington, Oregon and California, which account for about 70% of the total United States production.

Of the entire crop (1,600,000 tons, 1941–45 average), about one-third is canned, dried, frozen or made into jams, preserves, jellies and spirits. California accounts for 90% of the processed peaches in the United States, and about half of its own peach crop is processed. The bulk of the peach crop in eastern and middle western States is marketed as fresh fruit, and it is only in California that one could consider peach pits as a source of oil and other by-products.

At the present time peach pits can be obtained from the canneries and drying yards for little or nothing except cost of hauling. High-proof spirits are made

from the juice extracted from clingstone pits, and the pit itself is converted into char for poultry feeds and fuel briquets. Very little peach kernel oil is extracted because most of the pits available for by-products are from canners' clings, which in the original wet condition yield less than 1% of oil, and because modern canning practice in many plants utilizes a saw which cuts the entire peach, including pit, in two, badly crushing the kernel and making it difficult to recover the fragments.

It will be noted that while clingstone varieties are favored for canning, freestone peaches are preferred for drying. The pits are usually obtained from the latter in whole condition, which renders them more suitable for cracking and recovery of kernels. Brine flotation is used as for apricot pits. Eleven tons of dry freestone peach pits yield about one ton of kernels. Oil may be recovered in screw presses, but in the one plant now operating in California on peach pits hydraulic presses used in hot pressing of olive oil are employed.

Cherry Pits. Types of processed cherries marketed pit-free that will be considered here are canned, frozen, miscellaneous packs of sour varieties, and also brined sweet and sour cherries. The major States in production of processed cherries in these classifications are Michigan, New York, Wisconsin, Washington, Oregon, California and Pennsylvania, which account for 85% (78,000 tons, 1941–45 average) of the total. California raises no sour cherries commercially, but there is extensive brining of sweet varieties. The oil represented by the total of pitted cherries amounts to about 1,100 tons per year, but no plant is at present recovering any of it. One company in Wisconsin is known to have produced a few tons of cherry kernel oil a few years ago. Another used cherry pits as a source of " oil of bitter almonds " produced by steam distillation of the ground meats.

Plum Pits. The amount of plums processed per year amounts to about 4,000 tons (1937–46 average). The pit oil represented by this quantity of fruit is insignificant. The principal areas where canning of plums is practiced are Michigan and California.

Fruit Pulp Oils

The oils to be considered under this heading are those from avocado and olive. The latter is a particularly important oil of commerce, although supplies obtainable from olive growing in this country are not large when compared with world production. The two oils are quite similar in their high content of combined oleic acid. Reported percentages of oil in the fruit and composition of the combined fatty acids of olive and avocado oils are found in Table II.

Avocado. The culture of avocados in the United States is confined to Florida and California, the latter State accounting for 83% of the total production (20,270 tons, five-year average, 1941–45). From 1,000 to 6,000 tons a year are imported, principally from Cuba during the summer months. Commercial plantings in California are located almost entirely in climatically favored areas in the southern part of the State, particularly in the coastal belt from San Diego to Santa Barbara.

As the avocado is a luxury fruit, most of the crop is sold at prices which make oil recovery from any considerable portion of it out of the question. It is only in the spring that a small tonnage can sometimes be utilized for this purpose. The cull portion of the crop ordinarily represents only about 1% but occasionally may be considerably higher because of adverse conditions such as the heavy freeze of 1937.

The oil content of avocados may vary from 3 to 21%. The normal range is 9 to 15%. The percentage of oil is a criterion of grade, being highest in fruits

considered best for table use. Avocados are reputed to have a high content of vitamin A, which naturally passes into the oil, and the oil itself has been found to contain sufficient vitamin D to be protective against rickets. Because of the pulpy character of the fruit, avocado oil is not easily recovered by expression methods unless a fibrous medium such as peat moss is added, which of course increases retention of oil in the press cake. A process recently developed at Lindsay, California, for recovery of olive oil has been successfully used on avocados. With this method the fruit is pitted and macerated with water in a ball mill; the resulting slurry is screened and centrifuged to separate the oil. Yield is approximately 25–30 gallons of oil per ton of fruit, or about 10–12%.

Avocado oil has been reported to have a definitely favorable effect on skin disorders, such as eczema, but it is not sold and formulated for this purpose. The current market price for the oil is from $1 to $1.10 a pound. It is sold almost exclusively to the cosmetic trade.

Olive. Olive oil occupies a unique position among vegetable oils in that it is valued for its distinctive odor and flavor as well as for its low melting properties and adaptability to many cosmetic and pharmaceutical formulations. Unlike the common bland oils, such as cottonseed and corn oils, high-grade virgin oilve oil is not alkali-refined or steam-treated but merely water-washed and clarified. If the fruit has been properly stored prior to crushing, the oil will have a low content of free fatty acids.

California accounts for almost the entire U. S. production of olives (99.8%). Major producing areas are the San Joaquin and Sacramento valleys and a group of southern counties, particularly Los Angeles, Riverside, San Bernardino and San Diego. Principal varieties grown are the Mission, Manzanillo and Sevillano. About half the acreage is planted to Mission which is a fairly good variety for oil. In prewar years California produced only 5 to 10% of our national olive oil requirement. Olives devoted to this purpose have never yielded the domestic grower as high a price as those sold for canning, but demand became so great when Mediterranean supplies were shut off that the price of the former rose from about $75 a ton in 1940 to about $220 a ton in the early months of 1947. Olive oil prices in this period rose from about $2 to about $8 a gallon. From 1941 to 1945, inclusive, about 50% of the total olive crop was used for oil production. With resumption of olive oil imports oil prices have begun to decline.

The oil content of ripe California olives ranges from about 10.7 to about 33.7%, averaging 18 to 25%. Of the total present about two-thirds is recoverable as " virgin " oil.

Many attempts were made during the years of olive oil shortage to extend the limited amounts available from the Cali-

TABLE II

FRUIT PULP OILS

Kind	Oil	I.V.	Characteristics of Oil: Composition of Fatty Acids		
			Oleic Acid	Linoleic Acid	Sat. Acids
			Percent	*Percent*	*Percent*
Avocado	3-21	70.6-94.4	77.4	10.75	7.2
Olive	15-60	74-94	69.1-84.4	3.9-12.0	9.3-17.2

fornia crop. No doubt considerable adulteration with cheaper oils occurred as well as addition of refined hot-pressed or solvent-extracted olive oils to virgin grades. One process for producing an olive-flavored oil was publicized and practiced, in which olive paste was first macerated with a cheaper oil, such as cottonseed or corn oil before pressing. This process was claimed to provide a blend carrying more of the typical olive-flavor than would be possible by merely mixing a bland oil with olive oil.

In addition to the conventional hydraulic pressing which has been used for many years to recover olive oil and the centrifugation process described in the section on avocado oil, a number of other methods have been operated or proposed, several of which are reviewed briefly in Dr. G. S. Jamieson's book on vegetable oils.

Seed Oils

More numerous and variegated than the oils from the pits and fleshy portions of fruits are those from a host of miscellaneous seeds which are or could be by-products of food-processing industries. Included in this list are several oil-bearing seeds which are raised for oil production (although in small amounts compared with soybeans and flaxseed, for instance) or used for other purposes such as feed. Others are still in the development stage. Omitted are the seeds of fruits and vegetables which are sold mainly in the fresh condition or, if processed, without removal of seed from a substantial portion of the product. Of those omitted, watermelon, cantaloupe and fig seeds are examples. Table III summarizes reported figures for percentage of seed in fruit or vegetable, kernel in seed, oil in seed, and characteristics of the oil.

Seeds of Fruits

Citrus Seeds. In the years 1941–45 an average of 19% of the oranges, 53% of the grapefruit and 30% of the lemons grown in the United States were processed for juice, concentrates, fruit segments and other citrus products. These figures, however, include noteworthy amounts of seedless grapefruit and oranges.

Of the four States (Florida, Texas, Arizona, California) that produce grapefruit in commercial quantities, Florida and Texas by far exceed the other two, but only Florida processes seeded varieties in tonnages large enough that the seeds might be considered a source of vegetable oil. The average tonnage of seeded grapefruit processed in Florida during the five seasons, 1941–42 to 1945–46, was 476,600 tons, of which the dry seed equivalent, at 1.9%, is 9,050 tons. This would be capable of yielding 2,850 tons of oil, based on 31.5% for recoverable oil in the seed. At the present time a plant is operating at Lakeland, Florida, for manufacturing citrus by-products, which includes the recovery of seed oil in considerable amounts.

Of the oranges processed in this country only the Valencias need be considered as sources of oil-bearing seed. For the period 1943–44 to 1945–46 the processed Valencias (annual averages) were divided as follows:

California	219,000 tons
Arizona	65,500 tons
Florida	377,460 tons
Total	661,960 tons

The seed content for oranges is greatly variable, but 0.3% is a fairly good average figure. Based on this factor, the seed equivalent for the total of the Valencia oranges processed is about 1,986 tons, which at 40% would yield about 790 tons of oil.

In a study of the Western Regional Research Laboratory it was learned that orange-seed oil could be refined, bleached and deodorized to a pleasing bland prod-

uct useful for foods and other purposes. In composition of glycerides it resembles cottonseed oil.

Lemons, unlike oranges, are not a seasonal crop. Fruit may be found on a given tree in all stages of ripeness. Seed content of lemons is an exceedingly variable quantity, depending on climatic conditions during ripening. It is an interesting fact that a cold snap or freeze will be followed, after a fixed time interval, by a crop of lemons having an abnormally high seed content.

Lemon seeds can not be counted on as a prolific source of oil. The tonnage of processed fruit is subject to wide variation from year to year, and, as the seed content is also variable, a figure for potential annual oil yield is difficult to reach. Based on the three-year average, 1943–44 to 1945–56, a possible oil yield of about 540 tons can be computed if it is assumed that the content of dry seeds is 1.25% and the recoverable oil in the seed is 31.5%.

Grape Seeds. More than 90% of our national grape crop is grown in California, where the 500,000 acres in vineyards is more than double that devoted to oranges. Here we find principally the Vinifera, or Old World type of grapes, whereas the Great Lakes region, particularly New York and Ohio, is a center for the production of the Labrusca, or slipskin type, of which the Concord is representative.

Although California grapes are divided into three main classes (wine, table, and raisin varieties), the distinction between them is by no means absolute. For example, any variety of each of the three groups is suitable for wine, but the so-called wine varieties, with rare exceptions, are suitable for wine only. Raisin varieties are the most versatile, as they are also fine table grapes and are used plentifully for the manufacture of wine, brandy, and for canning.

Grape seeds that result from commercial processing and therefore may be considered sources of oil and other by-products, are to be found in the wastes from both the raisin and wine industries, particularly the latter. In former years raisins were made almost exclusively from seed-bearing grapes, principally Muscat, and large quantities of seed were rejected from drying plants and used for making brandy, oil, tartrates and stock feed. When the Thompson seedless was developed, the tonnage of Muscats converted to raisins dwindled, and in 1946 less than 27,000 tons of this variety were dried. In terms of vegetable oil this is equivalent to about 120 tons. Another factor that has drawn Muscat grapes away from the raisin field is the demand for them in the manufacture of Muscatel wine.

The flourishing wine industry in California has made available large quantities of grape pomace, from which seed can be readily separated by either dry or wet methods. At least three mills in California are now producing grape-seed oil by extraction from the seeds of wine pomace. It has been estimated that on the basis of an annual crush of a million tons of grapes the quantities of recoverable oil would be in the neighborhood of 3,200 tons if all the pomace were processed and all the seds obtained therefrom were extracted.

The wine interests of California for a number of years have been increasingly interested in possibilities of by-product manufacture from their pomace piles which have constituted a serious disposal problem. The commonest practices in the past have been to dry and burn the pomace or use it directly in the vineyards for fertilizer, but neither of these is satisfactory. If pomace piles stand idle for even a short time, putrefaction sets in and they become a health hazard to the community. Certain factors are important in a consideration of the economics of by-product recovery from a low-grade, high-moisture mate-

TABLE III
OILS OF VARIOUS SEEDS

Kind	Seed in Fruit	Kernel in Seed	Oil in Seed	Characteristics of Oil					
				I.V.	Composition of Fatty Acids				
					Oleic Acid	Linoleic Acid	Other Unsat. Acid	Sat. Acids	Unsaponi-fiables
	Percent	Percent	Percent		Percent	Percent	Percent		Percent
Orange	0.3	62-70.8	34.2-45	98-105.4	36.6	36.5	Linolenic, 0.6	26.3	0.95
Grapefruit	1.9	77	28-35	101-106	19.7	48.8	..	26.6	0.7
Lemon	0.5-2	..	30-35	103-109	..	..	..	..	..
Tomato	0.5-0.6	..	18-23	107-125	45	34.2	..	18.3	0.7
Grape	3.5-4	54	6.8-22	105-160	10.0-34.5	54-71.4	..	8.4-15.0	0.8-2.8
Squash	1.5	..	36.6	121	36.6	43.3	..	18.9	..
Pumpkin	1.5	..	30-35	120-130	25	45	..	30	..
Sunflower	..	54-61	27.5-30.8	122.4-136.6	21.1-39.1	51.2-68.3	..	9.7-12.8	..
Safflower	..	47.6-52.4	24-33.8	143.3-149.8	14.7-17.3	76.6-79.0	..	5.0-6.7	..
Apple	< 1	63.5-71.5	18.0-25	104-122.4	..	..	..	6.6	1.1-1.7
Pear	< 1	60.5-69.3	21.4-25	124.1	..	..	..	9.8	1.0
Rice bran	..	8-9.5 (Bran in rice)	8.7-20.4 (In bran)	92-109	38.7-45.3	26.4-42.0	..	14.8-21	0.7-5
Watermelon	..	..	20-30	133.8	13	63.4	..	15.2	1.2
Okra	..	50	12.8-22.0	91.1-100.3	41.5-43.7	25.5-29.7	..	28.8-30.0	1.1
Mustard (white)	..	..	25-30	94-106	28	19.5	Erucic, 52.2	4	..
Castor	..	..	35-55	82-90	7-9	3-3.5	Ricinoleic, 80-86	Dihydroxy stearic, 2.1	1.8
Tobacco	..	..	30-46	117.8-151.6	12.0-30.2	54.6-77.3	..	7.4-15.2	0.6-3.1
Cranberry	..	..	20	169.2	..	..	..	..	..
Asparagus	..	..	12.8	137	..	..	..	..	..
Wild plants									
Brassica arvensis (Charlock oil)	..	..	25.0-25.6	121	..	..	..	..	..
Brassica juncea	..	..	31.8-34.0	129	..	..	..	..	..
Tumbling mustard	..	..	32.6	151	5.2	19.0	Palmitoleic, 1.0 Erucic, 25.3 Linolenic, 34.0	14.1	0.5
Hare's ear mustard	..	..	29.5-36	99-107	20-30	15-20	Erucic, 35-45	4	..
Pennycress	..	..	32-35	117.3-123.2	12.1-12.5	32-33	Erucic, 49-53.4	2.5-5	0.8-1.5
Gopher plant	..	..	47.3	82.0-84.7	84.3-90.6	2.3-7.0	..	5.7-7.7	..
Wild cucurbits	..	..	28-31	122.7-131	..	37-43	..	..	1.1
Jojoba	..	..	48-50.8	81.7-86.3	0.7	..	Eicosenoic, 30.3 Dicosenoic, 14.2	1.6	48.3
Cattail seed	35-40	..	17.9	130.8	11.6	73.6	..	14.8	..
Pinus monophylla	..	..	21	102.1	56.7	31.6	..	8.5	1.9
Pinus sabiniana	..	..	11.5	120	50.5	45.2	..	4.3	..

rial like pomace, chief among which is the geographical distribution of the wine industry. The following pertinent facts are therefore set down as an aid in evaluating this factor:

1. Of a total of more than 400 wineries in California, about 60 account for 80% of the annual crush. All of these handle in excess of 1,000 tons of grapes per year. In one district, the southern San Joaquin Valley, 90% of the wine and brandy coming from that area is made by the larger wineries.
2. There are five major producing districts in California: the northern San Joaquin and Sacramento Valley, southern San Joaquin Valley, North Coast, Central Coast, and southern California.
3. The total crush for the Sacramento and San Joaquin Valley districts is about 80% of the State total.
4. The total crush, excluding Thompson seedless grapes, by the larger wineries in the Sacramento and San Joaquin Valley districts is 43% of the State's total for all grapes crushed and 62% of the total seed-bearing grapes crushed.
5. The oil represented by the pomace from the larger wineries in the San Joaquin and Sacramento Valley districts is about 2,000 tons per year, and from all wineries in those districts, about 2,400 tons.

The northernmost of the two areas mentioned (the northern San Joaquin and Sacramento valleys, not including the counties of minor importance) is an area roughly 80 miles long and about 50 miles wide. The southern San Joaquin district is about 40 by 100 miles in extent. Between is the county of Merced, in which wine production is relatively small. It is logical, therefore, that separation of grape seeds and recovery of oil has developed in these two areas. In the southern there are already two solvent plants which extract grape seeds, besides other oil-bearing materials, and another close to the northern district. Some lots of grape seeds were brought into the San Francisco area during the war years when oil supplies were short, but the results obtained with screw presses were not favorable. It has been our experience at the Western Regional Research Laboratory that ground whole grape seeds can not be handled well in this type of equipment. Oil yield is low and the cake tends to clog at the choke ring. Decorticated seeds, however, were quite satisfactory and contain upwards of 30% oil. Solvent extraction of grape seed as now practiced is not wholly satisfactory because of difficulty in filtering the miscella.

At the present time only a fraction of the available wine pomace in the two districts mentioned above is worked up for oil and by-products. The skins and portions of the pomace other than the seeds are dried and sold as a low-grade stock feed.

Grape-seed oil is excellent for culinary purposes. A product obtained from raisin seed is used to coat packaged raisins to make them free flowing. Although a wide range of iodine values from all sources are reported in Table III, American grape seeds usually yield an oil between the limits of 125 and 137. It has been used together with other oils in paint formulations.

Apple Seeds. Seventy percent of domestic apples used in processing are raised in the Western and North Atlantic states. The portion of the annual apple harvest converted to canned, dried, frozen and miscellaneous products is about 620,000 tons (1943–45 average) which, at 0.25%, would yield 1,550 tons of seed, the oil equivalent of which at 25% is 385 tons. Economical recovery, however, would probably be limited to the larger districts mentioned above, in which case the maximum oil recovery would be only 270 tons. Only large packing centers would be justified in separating seed from waste and would in most instances dispose of the seed to oil mills.

Apple-seed kernels contain about 1% of amygdalin and are therefore a poten-

tial source of oil of bitter almonds. It has been reported that apple-seed oil contains a muscle-regulating substance, probably a vitamin, but no confirmation of this statement has been found in the literature.

Pear Seeds. California and Washington are centers of production of pears for canning, drying and other uses, accounting for 90% of the national total, or 240,000 tons (1944–45 average). The output of processed pears in California is roughly double that of Washington.

The seed content of pears is greatly variable, but if the same figure (0.25%) is used as for apples in computations, the amount of recoverable oil represented by all the pears processed in the two States is about 150 tons.

Pear-seed oil is very similar to apple-seed oil in iodine value and saponification value, but no determinations have been made on composition of the fatty acids. Unlike apple seeds, pear seeds contain not more than a trace of amygdalin.

Cranberry Seed. Principal producing States for cranberries are Massachusetts, New Jersey, Wisconsin, Washington and Oregon. The two western States account for only 3 to 4% of the total. Average total production of cranberries for the five-year period, 1941–45, was 32,500 tons. Of this amount only 11,000 tons were made into seed-free manufactured products (principally sauce), the seed equivalent of which was about 110 tons containing about 22 tons of oil. The oil is said to be rich in vitamin A.

By-product manufacture from cranberry wastes is carried on by a cooperative, operated by grower members in the three largest producing States, at a plant in South Hanson, Mass. More valuable than the seed oil is the ursolic acid in the skins, which is potentially available to the extent of 10–15 tons a year.

Ursolic acid in the form of its sodium salt is a powerful agent for producing water-in-oil emulsions.

Oils from Seeds of Vegetables and Other Domestic Plants

Rice. As a supplementary bulk oil of commerce, the oil of rice bran is much greater in potential volume than any other described in this paper with the exception of tobacco seed oil. It occurs in the bran in the amount of 15%, although practical yields are 10–12. In general characteristics it resembles cottonseed oil.

Annual production of rice in the United States amounts to about 1,400,000 tons (1941–44 average). The area devoted to its cultivation is fairly large, 1,450,000 acres, and is confined to relatively few geographical districts: the San Joaquin and Sacramento valleys of California, southwestern Louisiana, eastern Texas, and Arkansas. Practices in cultivating, harvesting and milling vary somewhat with the locality, variety of grain and season, and these differences may be reflected in variations in the quality of both products and by-products.

Rice is usually milled at or near its point of origin. Milling consists in dehulling, separation of the bran from the endosperm, and finally polishing the kernels to yield the familiar white milled rice of commerce. The fractions of product and by-products are obtained in the following ranges:

Hulls	17–21%
Bran	8–9.5%
Polish	1–3%
Milled rice (including broken grains)	64–68.5%

The oil of rice is concentrated almost entirely within the bran which is also a storehouse for vitamin B. The bran is used widely in poultry feeds, but it is not entirely acceptable because of its tendency to become rancid in a short space of time. The oil is affected and develops large quantities of free fatty acids. It is common knowledge at rice mills that whole rice which has been adjusted to a moisture content of about

15% withstands storage very well, but if the hull is removed, lipolytic and/or oxidative changes in the bran oil begin to take place immediately, and this is true of both stored brown rice and rice bran. Extracted bran, on the other hand, can be stored quite well and is more acceptable as a constituent of feeds than the oil-containing bran. In more than one instance it has been used as a source of B vitamins.

Rice bran can be solvent-extracted without pretreatment of any sort. A number of plants produce rice bran oil, including at least three in California. Although refining losses are almost invariably high because of rapid development of fatty acids, the oil, if obtained from bran of sound grain and promptly extracted after milling, is reputed to be quite stable and is excellent for culinary purposes. It has long been used in the Orient.

Several types of physical and chemical treatments for preventing deterioration of the oil fraction of rice have been proposed, but to date none of them has been found practical for large-scale commercial application. No lipase has been isolated from the bran, although it is quite evident that some substance is present that acts like a lipase. The amount of rice bran oil potentially available is from 16,000 to 20,000 tons (computed from the average rice crop for 1941–45).

A recent trend in rice milling has been the production of so-called processed rice. This is an " infused " rice; the unhulled grain is treated with hot water and steam to an extent that a portion of the oil and vitamins is driven from the bran into the endosperm. When the hulls and bran are subsequently removed, the product is lightly colored and vitreous in appearance. In the debranning and dehulling, breakage is considerably less, probably because of gelatinization of the starch granules to such an extent that about a third more first-grade saleable rice is obtained than in the case of white rice. It is finding wider consumer acceptance. The necessary equipment for producing the material is simple in construction and inexpensive to operate, and the increased returns obtainable from the finished product more than offset the additional operating cost. This discussion is introduced to indicate a development in the technology of rice processing which is reflected in the changed character of the by-products and more particularly the bran and bran oil which are rendered more stable, that is, less susceptible to rancidification.

Sunflower Seeds. Up to the present time production of sunflower seed in the United States has been quite limited (2,400 tons per year, 1941–45 average). Localities in which it is grown are principally California, which accounts for about 80% of the total, and Missouri (15%). Small amounts are raised in Illinois. The oil equivalent of the total sunflower seed crop is about 360 tons, but all of the domestic crop at present is consumed entirely in feeds. During the war sunflower seed oil was imported in large quantities, principally from Argentina, and used largely in the manufacture of shortenings. In postwar years these supplies have fallen off.

Considerable experimental development in the raising of sunflowers has been going on in Canada for a number of years and more recently in the United States, particularly Illinois. The investigation of Milner *et al* includes a comparison of four common varieties of sunflower, which shows no large differences in the oil content of whole seed, but noteworthy variations in iodine value and corresponding variations in the content of oleic and linoleic acids (Table III).

Safflower Seeds. Repeated attempts have been made to establish safflower as an oil-seed crop in the United States, but with varying degrees of success. Yields per acre in test plantings have

been low in a number of instances, although near Prosser, Washington, 50 to 75 bushels were obtained in one instance and 70 bushels in western Nebraska under conditions of irrigation. Rabak reported as high as 40 bushels per acre without irrigation in the northern great plains under favorable climatic and cultural conditions, and as high as 50 to 65 bushels under irrigation. Low yields (20 bushels) in the Yakima, Washington, district have been reported. Central and eastern Nebraska (25 bushels) as well as the area near Havre, Mont. (7 to 12 bushels), seem poorly adapted to safflower. For a number of years small acreages of safflower were grown in the area near Deming, New Mexico, and in 1947 about 500 tons were produced in eastern Washington and northern Idaho.

More recently safflower has been gaining prominence rapidly in certain areas of western Nebraska, eastern Colorado and California. At least three oil mills are processing it.

Safflower (*Carthamus tinctorius*) is a glabrous herb yielding seed weighing from 40 to 48 pounds per bushel. It has been cultivated in India and Egypt for many years. The seed, as well as the press cake from oil extraction, is a valuable stock feed.

The oil content of safflower seed is somewhat variable, depending on variety as well as soil and climatic conditions. Although the range of 24 to 33.8% covers the usual oil content, percentages as low as 10.44 have been reported.

Extensive tests have been made on the use of safflower oil, which has drying properties, in coating compositions. Carrick and Nielsen reported that safflower oil blended with linseed improves resistance to weathering. The oil, when heated for 150 to 180 minutes at 310–315° C., polymerizes to a stiff gel soluble in turpentine. In India this material is known as " roghan " or " afridi wax ".

Tomato Seeds. Tomato production for manufactured products averaged 2,893,000 tons in the five-year period 1941–45. If it is assumed that seeds represent 0.55% of the whole tomato and contain 15% of recoverable oil (estimate from one solvent extraction plant in California), the potential annual supply of tomato seed oil is about 2,400 tons. The press cake from tomato seed is rich in protein (30–40%) and is acceptable as a stock feed.

In years past the Department of Agriculture has investigated tomato seed as a source of fixed oils and the general subject of utilization of tomato waste. These studies included the important incidental factors, such as handling and sorting tomato waste, cleaning the seed, extraction and refining of the oil, cost analysis, and possible returns. At the time of this investigation only 400 tons of tomato-seed oil were potentially available; since then, as already indicated, the amount has risen considerably and the general economic picture is greatly different. One vitally important factor is the crying need today for some means of disposing of tomato waste other than discharging it into streams where it causes widespread pollution. Ordinances against such practice are becoming increasingly severe, and tomato processors are seeking means whereby the pomace can be converted into products that will at least off-set the cost of handling and processing. A number of plants at present merely dry and sell whole tomato pomace for feed. In at least one instance seed is commercially separated from skins and sold for oil recovery. Both of these materials have been found to have a carotene content greater than 350 p.p.m.

Freshly expressed tomato seed oil is brownish to reddish in color and has a strong odor. After caustic refining, bleaching and deodorizing, a pale yellow product is obtained which is entirely suitable for culinary purposes.

The tomato processing industry is widespread. Canneries are located in

many parts of the country. This lack of centralization, together with the fact that the potential supply of tomato seed oil is small, means that an oil recovery set-up in connection with any one plant would most likely be uneconomical to operate unless other oil-bearing materials are also available for processing.

Squash and Pumpkin Seeds. Indiana is the principal processing center for pumpkin and squash (25–30% of national total). Illinois accounts for about 15–20% and California 10–15%. Other States where canning and/or freezing of these vegetables is practiced are Ohio, Washington, Oregon and New Jersey. The total annual pack in terms of fresh produce is about 82,000 tons (eight-year average, 1937–44) from which about 1,230 tons of seed would be obtainable, the oil equivalent of which is about 430 tons.

No pumpkin or squash seed oil is being produced at the present time in this country, but in Europe it has been recovered and used for edible purposes. A nut-like delicacy is made by roasting and salting the kernels of pumpkin seed.

Okra Seeds. Commercial plantings of okra as an oil-seed crop are not yet a reality, although several of the southern States, most notably Louisiana and Texas, have been experimenting with the raising of this plant and have reported favorably on yields. Indeed, the results are so promising that farm machinery companies are already developing special combines for harvesting it. Although related to cotton, okra is said to resist attack by the boll weevil and other insects, except nematodes. Separation of hulls and kernels of okra seed is somewhat difficult as the seed is small. Solvent-extracted or expressed oil from crushed whole seed has a greenish color, but this is readily bleached. The oil is reputed to have good stability after refining and hydrogenation.

An excellent discussion of okra seed oil by W. R. Edwards, Jr., and J. C. Miller appeared in the Chemurgic Digest for January 31, 1947. This article discusses use of the oil as an edible fat, feeding value of okra seed meal, processing of okra seed and its products, agricultural economy of okra seed production for industrial uses, and varieties and possibilities of new varieties of okra seed with high oil content.

Asparagus Seeds. On the San Joaquin and Sacramento river delta area of California are grown from 65,000 to 70,000 acres of asparagus annually; about 750 to 1,000 lb. of seed per acre could be obtained, or a total of approximately 26,250 tons, from which about 3,400 tons of oil are extractable. At the present time none of this oil is being recovered. It has an iodine value of about 137. Land devoted to asparagus culture in California is about one-half the national total. The next largest producing State is New Jersey where about 22,000 acres of asparagus are raised annually.

Mustard Seed. Considerable amounts of the Oriental variety of mustard are grown in Montana, the largest mustard-producing State in the country. This variety has an oil content of about 30% and yields a press cake that is not suitable by itself for condiment manufacture but may be incorporated as a filler with condiment mustard. The cake contains about 30% protein but is quite bitter, and if used in stock feeds, it must be kept below 5%. It is sold principally for fertilizer.

Other varieties of mustard grown principally for condiment manufacture are the brown and yellow mustards which have oil contents of about 25 and 20%, respectively. The larger manufacturers express the oil as a preliminary step in the making of food products. Proportions of the three varieties grown in 1946 were: Oriental, 33.6%; yellow, 54.9%; brown, 11.5%.

Mustard seed production in the United States amounts to about 21,500 tons per year (1941–45 average), having an oil

content of about 6,500 tons. The oil, because of its high percentage of combined erucic acid, is frequently used in place of rape oil for special lubricants. Although Montana is the principal producing State, accounting for about 78% of the total crop, significant amounts are grown in California, Washington, Oregon and North Dakota which produce mainly the yellow and brown varieties.

Rape Seed. The United States imports as much as 15,000 tons of rapeseed oil a year to supplement its meager supplies of high-erucic-acid oils. Although some rape seed is grown in northern Idaho and eastern Washington, it is still a minor crop. The Canadian production, which is sold almost exclusively to the United States, is steadily increasing. The 1947 crop, estimated at 14,600 tons, represents a 66% increase over 1946.

Tobacco Seeds. An approximation of the potential supplies of tobacco seed oil in this country is difficult because of differences in varieties as well as cultural practices. It has been estimated that flue-cured tobacco, which is grown on about 876,000 acres, would yield 80 to 320 lb. of seed per acre merely from the sucker growth which develops after the seed heads are topped. On the basis of these minimum and maximum values the potential seed crop would be 35,000 to 140,000 tons, of which the oil equivalent is 12,750 to 51,000 tons. The latter figure is more than three times the potential yield of the next largest minor oil described in this paper (rice bran). Riemenschneider and co-authors mention the possibility of growing *Nicotiana rustica* as a source of nicotine and drying oil. The Brasilia variety, without topping, has produced 100 lb. of nicotine and 1,000 lb. of seed per acre on the west coast. The oil, according to this author, is unusually stable, considering its high unsaturation.

Analytical data for tobacco seed oil (Table III) have rather wide ranges. The limits include values reported by all investigators. It should be mentioned that American tobacco seed oils usually have an iodine value above 135 and a content of combined linoleic acid in excess of 70%.

Castor Beans. In the early days of homesteading, raising of castor beans was practiced extensively in scattered localities in the Midwest. By 1850 there were 23 castor-oil mills in the United States located in Illinois, Missouri, Virginia, Tennessee, Pennsylvania, Alabama and Arkansas. St. Louis was the most important commercial center. Another mill, the largest of its kind, was erected in Jersey City in 1857 and began to handle imported seed. Domestic production reached a peak in 1879 and supplied more than the demand. Thereafter growing of castor declined and in some States, Kansas, for example, stopped almost entirely. Meanwhile imports began to increase, and today we rely entirely on foreign shipments, particularly from Brazil which supplies upwards of 90% of our requirements. Table IV summarizes briefly the past trend in domestic production and imports of castor beans.

TABLE IV

U. S. PRODUCTION AND IMPORTS OF CASTOR BEANS

Year	Production, Tons	Imports, Tons
1880	12,000	1,200
1900	3,300	3,400
1920	10	15,000
1940	..	154,000
1944	..	171,000

The value of castor oil as a lubricant for aircraft was recognized in World War I, and large amounts were produced and expressed for this purpose.

With the advent of World War II there arose an urgent need for castor oil, particularly by the armed forces, both as a lubricant and as an hydraulic fluid

in the operation of mechanized equipment, and, when dehydrated, as an ingredient of quick drying finishes. In the early years of the war the U.S.D.A., through the Agricultural Adjustment Administration, fostered the planting of castor, and several thousand acres in Texas were devoted to this purpose. Tests in the raising of castor were made in other localities, and much valuable information on the culture, selection and adaptation of varieties was obtained. It was learned that the region where soil, rainfall, growing season and freedom from disease are most favorable is the Ohio Valley and areas extending southwesterly into Kansas, Missouri, Arkansas, Oklahoma and Texas. In Florida successful test plantings have been made by a commercial concern. In the latter *Ricinus communis Africanus* was most satisfactory and under normal conditions yielded 600–900 lb. of beans per acre.

With the termination of the war the commercial raising of castor beans dropped, but in 1948 and 1949 small acreages were planted in Missouri, Oklahoma, Texas, New Mexico and California. One large castor oil company is projecting large plantings in the Central Valley of California.

The raising of castor beans domestically in competition with foreign supplies is difficult, principally because of the labor involved in harvesting. In most strains of castor the capsules holding the beans either drop or shatter when ripe, and for that reason mechanical harvesting has not replaced handpicking. This problem has been intensively studied in the University of Nebraska Chemurgic Project.

Castor is a versatile plant. Its leaves yield ricin, a potent insecticide, and from the stalks a quantity of bast fiber and alpha-cellulose are obtained. Castor oil is unique in being composed for the most part of glycerides of ricinoleic acid (12-hydroxyoleic acid). It has a high density and a low congealing point. It is used widely as a constituent of hydraulic brake fluids, as a low-temperature lubricant and as a liquid cushion in artillery recoil mechanisms. Its miscibility with low-molecular-weight alcohols is an important property in many applications of this sort.

Acylated castor oil or ricinoleic esters are valuable plasticizers. The sulfonated oil is the well known turkey red oil which has long been used in the dyeing of cotton textiles with alizarin. By appropriate chemical or pyrolytic treatment castor oil may be converted to a number of useful compounds such as sebacic acid, undecylenic acid, octanol-2, heptaldehyde and 12-hydrostearic acid.

Oils from Seeds of Wild Plants

Although wild plants can not be considered agricultural crops in any sense of the word, nevertheless, the oil-bearing potentialities of certain species are sufficiently great to warrant a short discussion of them in this article. The number of wild plants whose seeds contain oil, often in high percentage, is legion. In certain instances cultivation holds definite promise of substantial returns, particularly when the plants in question are resistant to drouth or insect infestations and bear prolifically. Some attempts are in progress at agricultural experiment stations and also in industry to grow various wild plants under the most favorable conditions and to establish by direct experiment the possible returns derivable therefrom, but these developments are slow to mature.

Few wild oil-bearing seeds growing in the native state are collected today except for food use in local areas. In almost every instance the cost of collecting enough of the seeds at a sufficiently low cost to justify processing is prohibitively high. When, on the other hand, such seeds are more or less constant by-

products of another crop, as in the case of grain screenings, and can be obtained without added expense, the picture is quite different. Many of the wild oil-bearing seeds of the United States have been discussed by Dr. Jamieson. A few of the more promising ones from the standpoint of the industrialist are included herein.

Jojoba. The jojoba (*Simmondsia Californica*) is a desert shrub indigenous to the southern parts of Arizona, New Mexico and California, where it grows plentifully. Many of the Indians living in these areas gather the jojoba beans and sell them in local markets. Eventually enough of them are assembled in one place to justify shipment to an oil mill for processing.

Jojoba beans are unique among oil seeds in that they do not contain the familiar glyceride type of oil but instead a liquid wax consisting for the most part of long-chain unsaturated esters of long-chain unsaturated fatty acids and alcohols, C_{20} and C_{22} being the predominant length in both. It is considerably more stable to heat than most glyceride oils. Although the oil or wax is non-nutritious, it has a number of important non-food uses. It is readily hydrogenatable to a hard wax, m.p. about 73–4° C., suitable for furniture, floor and automobile polishes. The beans, containing more than 50% oil, can be processed well in screw-type equipment which will express the oil down to about 5% in the cake. The latter contains more than 30% protein and is quite acceptable as a feed material.

The wax has been suggested for use as a lubricant for certain purposes and as a transformer oil in the electrical industry. The mixture of long-chain alcohols derived from jojoba wax by saponification has been patented as an ingredient of strongly emulsifying shortenings. Patents have been issued on the use of sulfurized jojoba oil as an ingredient of quick-drying printing inks, as a linoleum base and in the compounding of extreme pressure lubricants.

One experimental planting of jojoba was undertaken a few years ago by an industrial concern, but no decisive results on this venture have yet been reported. The shrub is dioecious; that is, staminate and pistillate flowers are borne on separate plants.

Grain Screenings. At least two plants in the United States, one at Great Falls, Mont., and one at Fresno, Calif., press or extract grain screenings brought down from western Canada. The screenings are collections of miscellaneous weed seeds together with some broken grain. Anderson *et al* have made a comprehensive study of the weed seeds in both cereal crops and flaxseed, collected in terminal elevators at Fort William and Port Arthur, including a determination of the oil content of both the individual components and the screenings as a whole. Cereal screenings contained about 14 kinds of weed seed, the principal ones being lamb's-quarters, wild mustard, stinkweed and hare's ear mustard. The amount of total foreign seeds and of individual species varied widely in different shipments. Refuse screenings from flax contained principally wild mustard, stinkweed, broken flax, hare's ear mustard and tumbling mustard. The current price paid for grain screenings is about $40 per ton, and the amount of oil recovered by the Montana plant alone in a season is about 1,100 tons.

The screenings from cereal grains, cleaned of straw, chaff and other foreign matter, showed an oil content of about 14.6% with an iodine value of 131. Flax screenings contained about 21.4% oil with an average iodine value of 143. The higher oil percentage and higher iodine value for the flax screenings, of course, are due to the considerable amounts of broken flax seed present. Meal from the pressing of grain screen-

ings can be fed to cattle if mixed with other feeds.

Wild Mustard. The wild mustard in screenings is made up of the seed of both *Brassica arvensis* and *Brassica juncea.* The latter is a plant cultivated in India for oil production. The proportions of the two show considerable variation in different grain shipments, but the effect of the variation on the constants of the oil is not great, as the total amount of wild mustard present does not exceed 31%, frequently is considerably less, and the iodine value of one is only eight points removed from that of the other.

Hare's ear mustard seed oil has been the subject of an investigation by Hopkins who found it had a content in combined erucic acid of 35–40% and an iodine value of 107. The percentage of oil in the seed was reported to be 29.5. Slightly different figures were found by Johnson and Greaves.

Tumbling mustard seed has an oil content of about 32.6% and an iodine value of 151. The percentages of combined fatty acids found are listed in Table III. The low value for erucic acid, 25.3% as compared with that of other mustards, should be noted.

Pennycress. This weed, also called fanweed, French weed, dish mustard, treacle wart, stink weed, bastard cress, devil weed and Mithradate mustard, is a principal constituent in the screenings of wheat grown in the northwest and north central States. It is a member of the Cruciferae, to which rape and mustard also belong, and contains, as might be expected, a large amount, about 49%, of combined erucic acid. Oil content in the seed is 31–35%. Test plantings conducted at Montana Agricultural Experiment Station have shown that on irrigated land 1,500 lb. of pennycress seed per acre can be obtained. Harvesting difficulties are encountered, however, in that the seeds do not mature evenly and the pods tend to shatter badly.

Pennycress seed oil is a potential substitute for rape oil which finds considerable use as an additive in special lubricants, particularly when blown, because of its marked ability to adhere to metal surfaces under heavy loads and to resist flushing by water. Such lubricants find wide application in the operation of both diesel and steam engines. The possible use of pennycress oil in coating compositions has been partially investigated.

The residual meal, after the oil has been extracted, is comparable in protein content with undecorticated cottonseed meal and nutritionally is quite adequate as a stock feed. It has the disadvantage, when fed to dairy cattle, of imparting an unpleasant flavor to the milk unless ingestion takes place a number of hours before the cows are milked.

Gopher Plant. Gopher plant, also called caper spurge and oily milkweed, is a biennial commonly found in fields and wasteland areas. The seeds yield about 47% of an oil with an exceptionally high content of oleic acid, highly laxative in the crude form. Indeed it is reported to have three times the laxative action of castor oil. Private test plantings have indicated the seed might be obtained in yields as high as 1,500–1,800 lb. per acre.

From the amount and kinds of fatty acids present (Table III) there is no indication that the glycerides are responsible for the oil's physiological action, and therefore the possibility exists that it might be suitably refined for edible purposes. The press cake, however, is either poisonous or obnoxious to animals and could not be considered as feed material.

Wild Cucurbits. In the arid region of the Southwest three wild gourds grow abundantly: *Cucurbita foetidissima, C. palmata* and *C. digitata.* The plants are perennial and produce large crops of fruit, the seeds of which are rich in oil and protein. The first of these was the

subject of a study by Wood and Jones in 1943; the other two were investigated by Ault and co-workers. The important constants for the oils as shown in these references are included in Table III. An unusual constituent of the fatty acids of these oils is a conjugated trienoic acid occurring in amounts of 10% or more. The acid is not identical with the elaeostearic acid of tung oil. Curtis estimated that the wild cucurbits might be capable of yielding 1,500 lb. or more of seed per acre.

Typha (Cattail). Processing plants with a capacity to handle in excess of 1,500,000 lb. of cattail heads annually are being operated in Minnesota and Wisconsin to remove the fibrous portion for the manufacture of insulation and shock-absorbing materials. The seeds represented by this quantity of cattail heads amount to about 600,000 lb. and would yield about 50 tons of oil. In the event that all the available cattail seed in the U. S. were to be extracted, about 17,000 tons of oil could be obtained, although, of course, the harvesting of a considerable portion of this wild crop would not be practical. Typha seed oil has an unusually high content of free fatty acids, the cause of which is unknown but may be the weathering of the seeds prior to extraction.

Piñon Nuts. Pine nuts of various kinds are harvested annually in considerable amounts in western and southwestern States by Indians and consumed as food. The Forest Service has encouraged this practice in projects for the development of stands of pine with maximum sustained nut production.

In Utah, Nevada and California, *Pinus monophylla*, and in New Mexico, eastern Arizona and southern Colorado, *Pinus edulis* are found in great abundance. Pine nuts from European species are imported into eastern States under the name " pignolias ".

No reliable data are available on the total potentialities of this wild crop or the practicality of collecting and processing the nuts for oil, as they are a food item and hence are probably of more value for this purpose than as a source of oil. One estimate of the harvested pine nuts in the southwestern States is 4,000 tons a year, the oil equivalent of which is about 2,500 tons.

Conclusion

This discussion of minor oil-bearing crops by no means includes all that were considered and might conceivably have deserved treatment or at least passing mention. Omitted were seeds contained in agricultural products from which, in all likelihood, oil could never be obtained economically. Justification for such reasoning can in most cases be found in the scattered status of an industry processing the commodity from which the oil-bearing part is derived, or the low magnitude of processing operations *vs.* that of retail sales. For example, the seeds of watermelon, cantaloupe and a wide assortment of berries were not included. A vast number of seeds of wild plants could have been discussed, but unless concentration of growth occurs either naturally or as a result of domestication or unless the derived oil seems to have outstanding characteristics, such as that of gopher plant seeds or jojoba beans, it is useless to consider them seriously as oil sources. Certain grain screenings, such as water grass which occurs plentifully in rice, were omitted because their oil content is too low for profitable recovery.

The evaluation of oils must usually be made on the same basis as the commoner bulk oils of commerce which they most closely resemble. As a rule vegetable oils differ from each other only in their contents of individually combined acids

and their distribution in the oil as triglycerides or in having a high percentage of an unusual acid, such as elaeostearic or hydnocarpic acid. Important variations, however, may occur in content of minor constituents, such as oil-soluble vitamins, antioxidants or prooxidants, and it must be recognized that no oil can be completely evaluated until quantitative measurements covering such substances have been made where their presence is indicated.

Utilization Abstract

Ginger. Ginger, one of the oldest of natural flavoring materials, is the rhizome of *Zingiber officinale* Roscoe, indigenous to Southeast Asia but cultivated in many other parts of the world, such as India, West Africa and the West Indies. The plant grows two to four feet tall, with its rhizome on the surface of the soil, and is cultivated at elevations of 600 to 1500 meters above sea level in districts with abundant rainfall and a warm humid climate. It bears an annual crop and is propagated by cuttings of the rhizome two inches long and bearing a bud. They are set out in ridges two to three feet apart, and about nine months later, usually in January or February, the flowering parts disappear and the rhizomes are dug up. The dirt is washed from them, and then they are scraped and dried in the sun. The product is known as " unbleached ginger ".

The following forms are known on the market:

a) Dried rhizomes with their adhering skin, classified as black, unscraped or coated ginger. This variety is the one most used as a source of the essential oil which is contained in the epidermis.

b) Scraped or uncoated ginger, the variety usually offered in powdered form for culinary purposes.

c) Sometimes the rhizomes are treated with sulphurous acid or chlorine and dusted with lime to give them a whitish appearance and to protect them against insects and mildew.

The principal commercial sources of ginger are Jamaica, India and Africa. That from Jamaica is the most highly prized from the aroma point of view and is the kind usually used for essential oil distillation and for making tinctures for flavoring purposes. The African variety from the West Coast, especially Sierra Leone, and the Cochin variety from India are used for obtaining the oleo-resin, since they yield a greater and more pungent product. There is also Calicut ginger from India. These varieties appear on the market in pieces one to three inches long.

The volatile oil is obtained by chopping the rhizomes into large pieces and distilling them with live steam. The Jamaica variety gives the best oil, but for cheapness the African and Cochin varieties are sometimes employed. The starch of the rhizome is retained in the various tinctures and extracts prepared for the mineral water trade and accounts for the cloud of ginger beer and related drinks. The pungency of ginger is due to its oleo-resin, or " gingerine ", which is obtained by extracting the powdered rhizomes with acetone, ether or some other suitable solvent, and evaporating off the solvent.

" In olden days it was a common practice for all mineral water makers to make their own ginger beer by fermentation from the root itself, and several of the old recipe books give formulas for so doing. These days it is usually more convenient to buy a ready-made extract from an essence firm. Many of these have been manufactured from fermented products. The fermentation process confers a taste to the product that is not perfectly imitated by other means. Ginger ales such as Belfast and Dry Ginger Ale are based on ginger with the addition of various flavoring agents, such as lemon, orange, rose, cloves and other bodies, which impart a much sought-after bouquet."

" The oleo resin of ginger is usually employed in the baking industry as it possesses valuable fixative properties and will stand up to the high temperatures employed ". (E. Bemfield, *Perf. & Ess. Oil Rec. 41: 136. 1950*).

Carbohydrate Sources For Ethyl Alcohol Production

Molasses and corn, the traditional sources of carbohydrate for the production of ethyl alcohol—for both industrial and beverage purposes—are being challenged by new sources. These were revealed by investigations undertaken during the last war emergency and by research within the industry which continues to investigate and evaluate potential sources of alcohol.

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Introduction

Before World War II practically all of the ethyl alcohol produced in the United States for industrial use was made by fermenting blackstrap molasses, while alcohol for beverage purposes was produced primarily from fermentations using three cereal grains—corn, rye and barley. There were several reasons for this:

a) Of the raw materials that were available for the production of alcohol, blackstrap molasses was the cheapest, easiest to handle and most economical to process. Moreover, it was available in large quantities, and the yield of alcohol from molasses fermentations was comparable to that from other raw materials.

b) Government regulations and tradition played an important part in limiting the producers of beverage alcohol to corn, rye and barley. The government regulations specifically state and limit the kinds and amounts of grains that may be used by the distiller for a certain type of beverage. For example, in order to label the product as malt, rye or wheat whiskey, 51% of the grain used must be malt, rye or wheat, respectively, and the product must be aged in new, charred, oak barrels. If 51% of the grain used is corn and the product is aged in new, charred, oak barrels, the distiller may call the product " bourbon whiskey ", and if more than 80% of the grain used is corn, the product may be aged in used barrels and called " corn whiskey ". In all cases the product must be distilled below 160° proof, i.e., it must contain less than 80% alcohol by volume. These government regulations are not very flexible and make few provisions for using raw materials other than those mentioned. When a distiller wishes to use new raw materials or vary his method of production, special permission must be obtained from the government. Furthermore, beverage distillers had used corn, rye and barley for generations, and these grains were plentiful, relatively cheap, and methods for their processing were well known. The beverage distillers also knew what alcohol yields could be expected from the use of these grains and what the quality of the product should be. Since the beverage distillers had been out of business for several years during Prohibition, it was necessary for them to build an inventory of aged whiskey as rapidly as possible and at the same time supply an ever expanding market. Therefore, there were definite reasons for them to investigate new technological means for in-

creasing their efficiency and rate of production, but there was little or no incentive for them to investigate new sources of raw material.

The advent of World War II, however, brought about large-scale production of ammunition, synthetic rubber, plastics and other implements of war, all of which required large amounts of ethyl alcohol for their manufacture. The requirements for industrial alcohol were so greatly increased that the existing facilities for fermenting molasses could not be expanded to meet the demand, and in 1942 it was necessary to curtail beverage alcohol production and to convert the beverage alcohol industry to "war alcohol" producers. At the same time import shipping became so erratic that large molasses alcohol plants were in danger of being shut down for lack of molasses, and these plants, therefore, were converted to use grain. Consequently the total grain-consuming capacity of the combined alcohol fermentation industry was greatly increased, and, since corn, which makes up the larger portion of grain used in the manufacture of alcohol, is also an important animal feed, it became increasingly necessary to investigate new sources of raw material for the production of alcohol in order to maintain an adequate supply of grain for feeding purposes. Many new sources were investigated, but only a few proved to be economically important.

This article will discuss the raw materials ordinarily used for the production of alcohol; some of the materials which have been used in times of emergency; and others which have been investigated only on a laboratory or pilot-plant scale.

Grain Alcohol

Production of alcohol by yeast fermentation of carbohydrate material is basically the same, regardless of the source of the carbohydrate. The following discussion of the processes involved in the production of ethyl alcohol is based on the use of grain, since the preparation of molasses for fermentation simply consists of diluting the molasses with water. The process can usually be divided as follows:

a) Preparation of the raw material for processing (milling).
b) Gelatinization of starch and sterilization of the mash by cooking with water.
c) Saccharification of the cooked starch by enzymatic hydrolysis.
d) Fermentation of the saccharified mash by yeast.
e) Distillation of the fermented mash to separate and concentrate the alcohol formed during fermentation.
f) Recovery of the dealcoholized residue for animal feed.

Like any other industrial process, the production of grain alcohol has undergone various modifications which have been designed to improve the efficiency and rate of production. For the purpose of this paper it is not necessary to give a detailed review of these developments other than to say that modifications have been made which permit the continuous flow of materials from one stage of the process to the next where formerly the process was batch-wise.

The grain is first passed through a series of cleaning devices to remove extraneous substances, such as pieces of metal, straw, stems and sticks. It is then stored in bins from which it is fed to the mills. After the grain is milled it is mixed with water and heated, either under atmospheric or high pressure, to gelatinize the starch granules. The cooked grain (mash) is then cooled to 145–150° F. and a slurry of barley malt is added. The enzymes present in the malt convert the starch into sugars which can be utilized by yeast. The converted mash, containing approxi-

mately 12% sugar, is cooled further and yeast is added. The yeast utilizes the sugar for growth and reproduction, and produces approximately equal amounts, by weight, of ethyl alcohol and carbon dioxide as metabolic by-products. After all of the sugar has been utilized, the alcohol is removed from the fermented mash by distillation.

The residue from distillation is called "wet stillage" and consists of the original nutrients in the grain, minus the starch, plus vitamins and other nutrients furnished by the yeast. This residue is sometimes fed to animals in the liquid condition, but more often is processed to produce dry products which can be easily stored and shipped. The wet stillage is screened and pressed to yield a fibrous material and a liquid. The liquid fraction containing most of the soluble nutrients is evaporated to a syrup and then dried on drum dryers to form a product called Distillers' Dried Solubles. The fibrous fraction is dried in rotary dryers to form a product called Distillers' Light Dried Grains; if the evaporated syrup is mixed with the fibrous portion and dried in rotary dryers, the product is called Distillers' Dark Dried Grains. These by-products are especially valuable in balancing animal rations containing large quantities of starchy grains. Table I compares the chemical and vitamin content of these by-products with the principal grain from which they are made.

TABLE I

COMPARATIVE CHEMICAL ANALYSES OF DISTILLERS' BY-PRODUCTS WITH CORN

	Moisture	Protein	Fat	Fiber	Ash
	%	%	%	%	%
Corn	13-15	8-9	3.5-4.0	2.5-3.0	1.5-2.0
Solubles from Corn	4-6	30-32	10-12	4.0-4.5	5-6
Dark Grains from Corn	8-10	27-29	8-10	12-14	3-5
Light Grains from Corn	8-10	22-24	5-8	14-15	3-5

Vitamins

	Thiamin*	Riboflavin*	Niacin*	Pantothenic Acid*	Choline*
Corn	1.5-2	0.6-0.7	6-6.5	3-3.5	175-200
Solubles from Corn	1.5-2.5	5.5-6.5	45-50	6-8	1,400-1,600
Dark Grains from Corn	0.8-1.0	2.5-3.5	35-40	4-5	1,000-1,200
Light Grains from Corn	0.5-0.8	1.0-1.5	15-20	1-2	240-260

* Milligrams per pound

Yeast

Yeasts used for the production of ethyl alcohol are selected on the basis of the rate and efficiency at which they produce alcohol and their ability to tolerate relatively high concentrations of alcohol. Practically all yeasts used in the alcohol industry are strains of the species *Saccharomyces cerevisiae*. Yeast is grown on a mash similar to that described above except that it contains more grain and nutrients. Most distilleries now employ a pure culture yeast procedure, i.e., yeast for inoculating-plant mashes is grown from pure cultures maintained in the laboratory. However, some distillers still prefer to use part of an actively fermenting yeast mash as an

inoculum for new yeast mashes. The danger of contamination inherent in this practice is great enough to strongly recommend the pure culture procedure, since contamination introduced at this stage of the process would result in gross contamination in the fermentation process which would reduce the yield and quality of the distillate significantly.

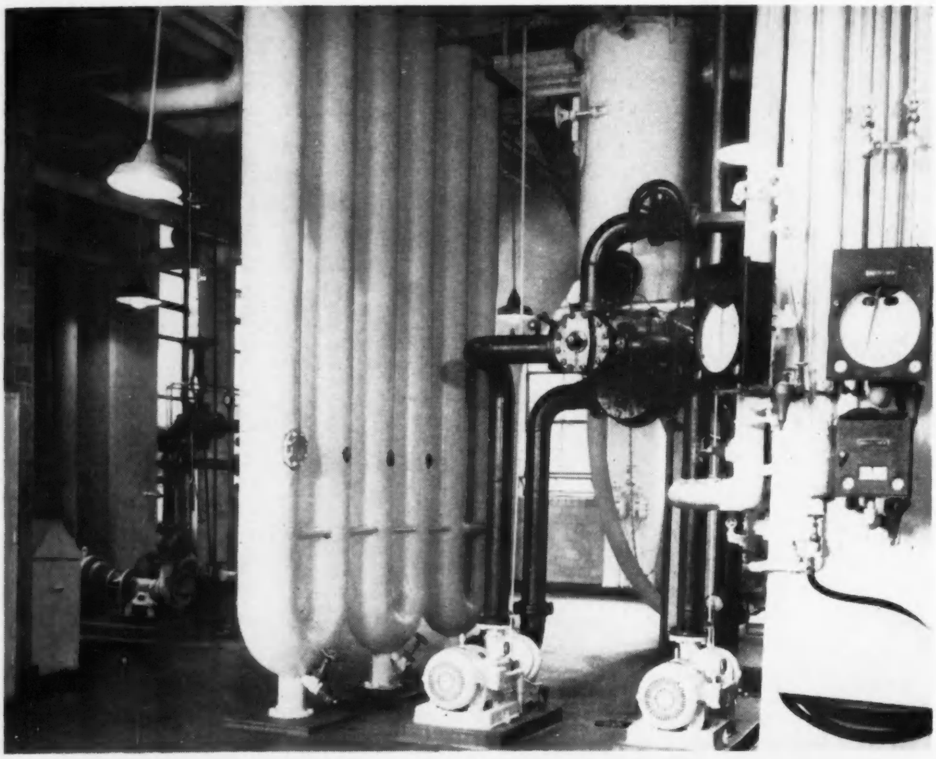
FIG. 1. Obtaining grain sample from car for analysis.

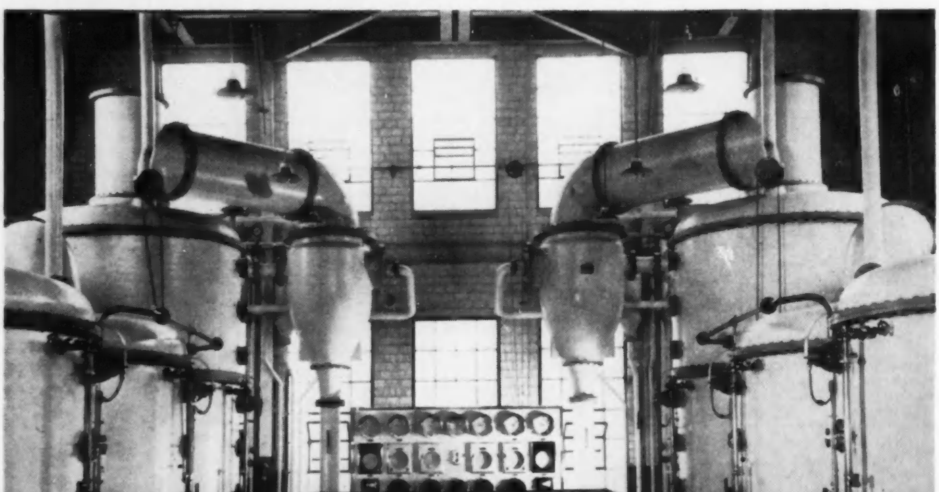
Fungal Enzymes for Converting Starch to Fermentable Substances

Fungi have been used for centuries in the Orient to hydrolyze proteins and to convert starch to fermentable substances. It has been only within recent years, however, that fungal enzymes have been seriously investigated by the alcohol industry in this country as agents for converting starch to sugar. Many species of fungi can be used for this purpose, but at the present time strains of *Aspergillus niger* and *A. oryzae* appear to be most satisfactory.

At first the fungi were cultured on bran, and the resulting "mold bran" was added to the cooked grain in place of malt. Later it was found that these fungi could be grown as submerged cultures.

Fungal enzymes can be obtained free of extraneous microorganisms, which is a distinct advantage over malt. Malt cannot be sterilized without destroying the enzymes present; therefore, a considerable bacterial load is introduced into the mash. Although this unavoid-





able contamination usually can be held in check by controlling pH and using a highly fermentative yeast which will rapidly bring the alcohol content up to a point where growth of bacteria is inhibited, bacterial contamination from malt is always a challenge and has made continuous fermentation of malt-converted mashes virtually impossible.

It has been shown in the laboratory and pilot plant that alcohol can be produced from mashes converted with fungal enzymes at considerable savings (depending, of course, upon the cost of malt) with no sacrifice in quality of product and with yields equal to, or somewhat better than, those obtained when malt is used. In addition, the use of fungal enzymes now makes continuous fermentation possible.

The Principal Raw Materials

The yield of alcohol from any source is dependent upon the amount of fermentable sugar that is present, or the amount of starch or other material present that can be converted into fermentable sugar. Therefore, the beverage distiller selects grain on the basis of high starch content, although in some instances grains containing less starch are used because of the specific flavor or aroma they impart to the distillate. The grains also furnish protein, vitamins and minerals for yeast nutrition, all of which are of value when the dealcoholized residue is used for animal feeding.

Corn. The term " corn " can be used to describe any of the cereal grasses. The most important cereal crop of a given region is often called corn, e.g., in England wheat is often called " corn "; in Scotland and Ireland the term is applied to oats; and in the United States, Australia and a few other regions " corn " refers specifically to varieties of Indian maize. Linnaeus named the latter plant *Zea Mays* from the Greek word " Zea " for cereal which in turn was taken from the verb meaning " to live ". *Zea Mays* L. has a normal chromosome complement of ten pairs, and, since most of the subspecies that have been described likewise have ten pairs, it is generally believed that these are agronomic groups and not true subspecies. On this basis only two groups are recognized in Federal standards of classification, dent and flint corn.

By far the larger portion of grain used in the manufacture of alcohol is made up of corn. Dent corn is the type used most often because it is the most readily available; however, flint corn is also satisfactory. Yellow varieties are preferred because the carotene content adds to the value of the by-products.

The larger part of the corn crop grown in the United States is dent corn. The kernels are deep, wedge-shaped and are characterized by a layer of hard, flinty starch on the sides, while between is the soft white starch which constitutes about one-half of the kernel. As the kernels dry, the white starch shrinks more than the flinty starch and a dent is formed in the top of each kernel, giving the ear a very rough appearance. Dent corn has a greater number of rows per ear than flint, varying from ten to 24, with the usual number being 16 to 20. Flint corn is characterized by the kernel having a hard flinty layer of starch over the entire crown which does not shrink as the grain dries. The kernels are oval, and in some cases there is a slight indentation on the top. Flint corn appears in all of the common maize colors. The ears have six to 12 rows and are eight to 14 inches long. It is grown in sections of the United States where dent corn will not have time to mature.

FIG. 2 (*Upper*). Continuous pressure cooker.
FIG. 3 (*Lower*). Evaporators used to concentrate liquid residue before drying.

TABLE II

APPROXIMATE CHEMICAL ANALYSIS OF CORN

	Water	Protein	Ether Extract	Crude Fiber	Carbohydrate other than crude fiber	Ash
	%	%	%	%	%	%
Maximum	12.32	11.55	5.06	2.00	75.07	1.55
Minimum	9.58	8.58	2.94	1.00	68.97	1.19
Mean	10.93	9.88	4.17	1.71	71.95	1.36

One of the greatest achievements in the field of agriculture in recent years has been the development of hybrid strains of corn. Over half of the corn now grown is hybrid, and in leading corn States it is estimated that 60–90% of the total crop is hybrid. The distilleries use yellow hybrid corn and have tried to interest several breeders in producing a hybrid strain with an exceptionally high starch content. Table II gives an approximate chemical analysis of corn.

Corn is an American crop and ranks first in total acreage and production among the various agricultural crops grown in the United States. Table III summarizes the trend of corn production in the United States for various years and also shows the amount of corn used in the production of ethyl alcohol.

It will be noted that the overall production of corn has not varied much since 1901, but that the price paid per bushel in 1947 was more than five times that paid in 1901. It is also interesting to note that the amount of corn used for the production of ethyl alcohol in normal times represents a relatively insignificant amount of the total crop. Nevertheless, the small amount of corn used by the distilling industry when added to that used by other industries is an important factor in determining the price the farmer will receive for his crop when it is sold for other purposes. The amount of corn used for alcohol production during both World Wars was comparatively large when compared with the normal consumption. Likewise, the increased amount of corn used for beverage alcohol after the war (1947) represents a temporary condition. During the war

TABLE III

CORN ACREAGE, PRODUCTION AND VALUE WITH AMOUNT OF CORN USED FOR THE PRODUCTION OF ETHYL ALCOHOL[1]

Year	Acreage Harvested (1,000 Acres	Production (1,000 Bushels)	Farm Value ($1,000)	Yield per Acre (Bushels)	Price (Cents per Bushel)	Used to Produce Ethyl Alcohol (1,000 Bushels)	Amt. of Total Crop Used for Ethyl Alcohol (percent)
1901-05	95,226	2,529,114	1,113,625	26.6	44.0	19,536	.77
1916-20	102,631	2,704,768	3,342,953	26.4	123.4	32,070[2]	1.19
1935	95,974	2,299,363	1,506,281	24.0	65.5	19,400	.84
1943	94,455	3,034,354	3,407,902	32.1	112.3	49,956	1.65
1947	83,981	2,400,951	5,640,283	28.6	235.0	47,355	1.97

[1]Statistical Abstracts of the U. S. Dept. of Commerce, 1948
[2]1916 only

very little beverage alcohol was produced and inventories of aged beverage alcohol were reduced rather drastically. Therefore, after the war the beverage distillers set out to replenish their aging stocks as rapidly as possible, and this, of course, was reflected in a higher consumption of corn and other grains. After these stocks have been replaced the consumption of these grains undoubtedly will return to about the pre-war level.

Rye. Rye is a member of the genus *Secale.* The cultivated varieties are sometimes divided into two species, *S. cereale* L. and *S. fragile* Bieberst. *S. fragile* is an annual grown in southwestern Asia, while *S. cereale* is the species commonly grown in the United States. The cultivated species have seven pairs of chromosomes, and attempts have been made to cross rye with wheat in order to combine the hardiness of rye with the quality of wheat, but thus far no successful varieties have been produced. Unlike other small cereal grains, rye cross-fertilizes freely and sterility often results when self-fertilization is attempted.

Some of the best varieties of *S. cereale* that have been developed are: Minnesota No. 2, Petkus, Ivanov, Rosen, Dakald, Mammoth winter, Swedish and Abruzzi. Rosen rye was developed by selection from a sample of rye sent from Russia in 1909; the variety matures rather late. The heads are large and well filled, and the kernels are large and dark green.

The large kerneled rye is preferred by distillers because it is easier to handle.

TABLE IV

APPROXIMATE MOISTURE, STARCH AND PROTEIN ANALYSIS OF DISTILLERS' RYE GRAIN

	Moisture	Starch[a]	Protein[a]
	%	%	%
Maximum	9.7	59.5	14.5
Minimum	8.9	54.5	9.3
Average	9.4	56.4	12.1

[a] As received.

However, the starch content of rye varies according to the climatic conditions during its growing period, and the distiller selects the type having the highest starch. Although the amount of potential fermentable material in rye is considerably less than that in corn (Table IV), rye is used for producing beverage alcohol because of the specific flavor and bouquet it imparts to the distillate.

TABLE V

RYE ACREAGE, PRODUCTION AND VALUE WITH AMOUNT OF RYE USED FOR THE PRODUCTION OF ETHYL ALCOHOL[1]

Year	Acreage Harvested (1,000 acres)	Production (1,000 Bushels)	Farm Value ($1,000)	Yield per Acre (Bushels)	Price (Cents per Bushel)	Used to Produce Ethyl Alcohol (1,000 Bushels)	Amt. of Total Crop Used to Produce Ethyl Alcohol (percent)
1901-05	2,323	30,640	17,570	13.2	57.3	5,411	17.6
1916-20	5,455	65,481	96,895	12.0	148.0	3,117	4.76
1935	4,066	56,938	22,677	14.0	39.8	10,240	17.98
1943	2,755	30,452	29,859	11.1	98.1	2,089	6.86
1947	2,022	25,977	63,180	12.8	243.0	4,235	16.30

[1] Statistical Abstracts of the U. S. Dept. of Commerce, 1948.

In many parts of the world rye fills much the same place that wheat does in the United States, but it is a minor crop in this country. Table V shows the trend of rye production in the United States and the amount of rye that is used in the production of alcohol. It will be noted that in normal times the distilling industry utilizes from 15% to 20% of the total harvest; the remainder is fed to livestock or used for replanting. The price per bushel, therefore, is dependent largely upon industrial demands for the grain and the corresponding supply.

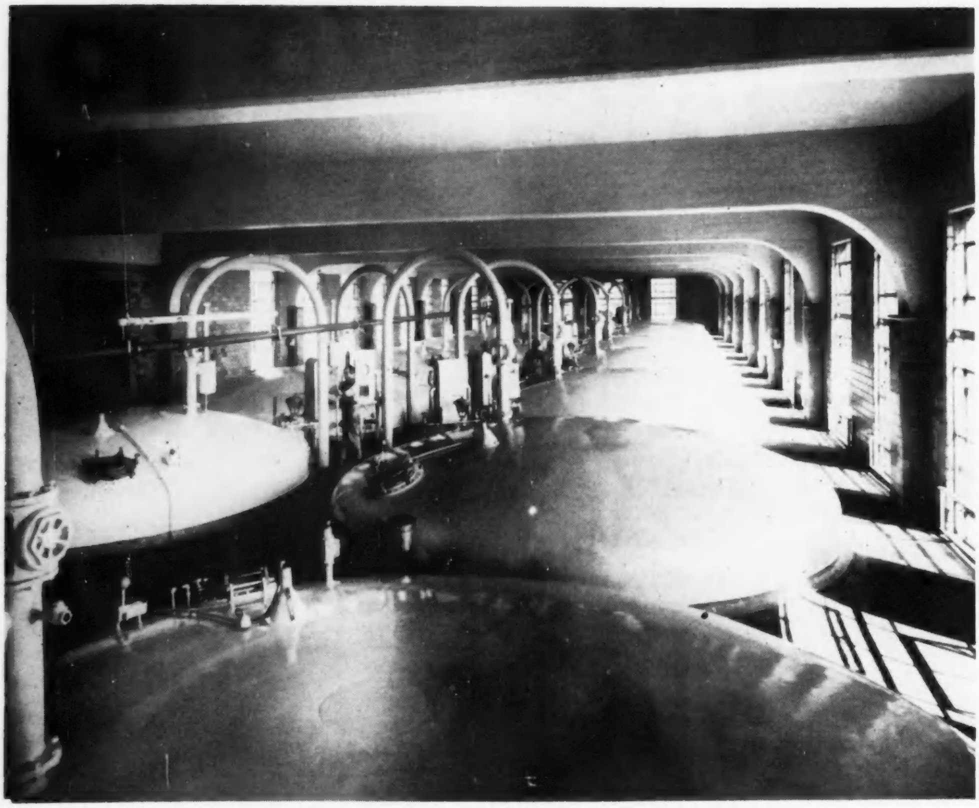


FIG. 4. View of fermenter room.

The distilling industry would welcome the development of a rye type having a higher content of starch. Some experimental crossings have been made in an effort to accomplish this, but since rye is readily cross-fertilized, it is difficult to develop pure strains and even more difficult to maintain them.

Barley. Barley is a member of the genus *Hordeum* and is one of the oldest cultivated grain crops. It has been used for food and feed since ancient times. Most of the cultivated varieties are believed to have originated from *Hordeum sativum*, and these are divided into two distinct types, two-row barley and six-row barley.

Barley is not grown so extensively as are some other grains because it does not lend itself to a wide variety of uses, and in the United States barley has become a rather specialized crop for regions where it grows best.

In the United States barley is used primarily as a malted grain or barley malt. The term " malt " can be applied to any sprouted grain; if barley is sprouted, it becomes barley malt; sprouted rye is rye malt, etc. In the distilling industry, unless stated otherwise, the term " malt " refers to barley malt. At times rye malt is used in combination with barley malt, and in some countries where barley is not available, corn, millet and wheat are used. Grain is malted in order to activate a system of enzymes within the seed. These enzymes are present in the scutellum and are released as soon as the grain is placed in an environment containing optimal conditions for growth, viz., moisture, warmth and air. The grain is placed in steep tanks containing water at 55° F. After the grain has absorbed an optimum amount of water it is placed in well-ventilated bins, warmed and allowed to sprout. As the grain sprouts, the amount of enzymes released from the scutellum increases and the enzymes convert the starch in the endosperm to sugars which are utilized by the growing embryo. If growth of the embryo is stopped while the scutellum is releasing enzymes, the enzymes remain in the grain. Therefore, after the grain has been allowed to germinate for a specific length of time—four to six days—growth is stopped quickly by drying the grain in heated rotary dryers. This reduces the moisture content of the grain so that danger of spoilage during storage is eliminated and further growth is impossible; the heat of the dryers is so regulated that the enzymes are not destroyed.

The yeasts used to produce alcohol are like the embryo in the seed; they cannot utilize starch. Therefore, the starch in grain must be converted into fermentable sugars. There are several ways of doing this, but it is general practice in the beverage alcohol industry to use the enzymes from malted grains. The malted grains are milled, mixed with water and added to the cooked grain (mash) at a temperature of 145°–150° F. The enzymes in the slurry of malted grain convert most of the starch in the mash to fermentable sugars in the same manner that they convert the starch of the endosperm to sugar during germination of the grain.

There are distinct differences in the types of barley malt used by distillers and brewers. The distilling industry requires a barley malt with a high concentration of enzymes and protein material and a low starch content, while the malt used by brewers can have a lower concentration of enzymes and protein and a higher starch content. The small six-row barley is best suited for distillers malt because it is a small-kerneled grain, low in starch and high in protein. High enzyme concentration is partially related to kernel size and is relatively greater in smaller kernels.

Although only 20% to 25% of the barley grown in this country is used for malting (Table VI), the premium price paid for barley that meets the specifications for malting has encouraged many farmers to produce barley having better malting qualities. It can also be seen from Table VI that the beverage alcohol industry normally utilizes only a small percentage of the total barley malt produced and, of course, an even smaller percentage of the total barley crop. The larger portion of malted barley is consumed by the brewing and food industry.

Black Strap Molasses. In pre-war years over 100 million gallons of industrial ethyl alcohol were utilized annually in this country. Approximately 68% of this alcohol was produced from imported blackstrap molasses and about 24% was synthesized from petroleum. Molasses, a by-product of the sugar industry, was cheap, could be obtained in sufficient quantities to assure year around production, was easy to handle, economical to

TABLE VI

BARLEY ACREAGE, PRODUCTION AND VALUE[1] WITH THE AMOUNT OF BARLEY USED FOR MALT[2]—AND THE AMOUNT USED FOR THE PRODUCTION OF ETHYL ALCOHOL[1]

Year	Acreage Harvested (1,000 acres)	Production (1,000 Bu.)	Farm Value ($1,000)	Yield per acre (Bu.)	Price (Cents per Bu.)	Used to Produce Ethyl Alcohol (1,000 Bu.)	Amt. of Total Crop Used to Produce Ethyl Alcohol (percent)	For Malt-Alcohol & Alcoholic Beverages (1,000 Bu.)	Amt. of Total Crop Used for Malt (percent)	Amt. of Malt Used for Ethyl Alcohol (percent)
1901-05	5,981	15,417	65,069	25.3	43.0	3,529	22.9	...	...	...
1916-20	7,858	173,712	174,922	22.1	100.7	4,481	2.6	...	...	...
1935	12,436	288,667	109,372	23.2	37.9	4,810	1.7	62,156	21.53	7.7
1943	14,768	324,150	320,979	21.9	99.0	9,979	3.1	83,314	25.70	12.0
1947	10,947	279,182	476,870	25.5	171.0	8,131	2.9	...	...	...

[1] Statistical Abstracts of the U. S. Dept. of Commerce, 1948
[2] Agriculture Statistics, 1948

process, and the sugar-producing countries exported it to the United States rather than process it into alcohol. Under these conditions alcohol produced from molasses could readily compete with synthetic alcohol. During the war, however, molasses imports were so erratic that there was danger of hampering the production of war materials and there was always the possibility that these imports would be cut off completely. Therefore, many of the large molasses distilleries were converted to use grain, and several new grain-processing industrial alcohol plants were constructed by the government. The government also expanded the production of synthetic alcohol from 25 million gallons per year before the war to over 70 million gallons per year during the war.

The new grain-processing industrial alcohol plants which had been constructed by the government during the war were not a serious post-war threat to the molasses-alcohol producers, since the price of grain made it impossible for industrial alcohol from this source to compete with alcohol from molasses. The synthetic alcohol industry, however, has continued to expand since the war, and, according to the annual report of the Treasury Department's alcohol tax unit for the fiscal year ending June 30, 1949, ethyl sulfate has now replaced blackstrap molasses as the chief source of industrial alcohol. Ethyl sulfate accounted for 43.82% of the industrial alcohol produced during the fiscal year ending June, 1949, while blackstrap molasses accounted for 33.88% of ethyl alcohol produced during this period. In addition, 8.2 million gallons of 95% ethyl alcohol were made from ethylene by a process which operated for only a fraction of the fiscal year reported by the Treasury Department. This source of alcohol will undoubtedly be greater during the next year, and blackstrap molasses may be displaced even further.

The molasses-alcohol industry is challenged further by the following problems which must be taken into consideration before any forecast can be made of the industry's future:

a) It is quite possible that the synthetic-alcohol industry can be expanded to such an extent that its annual production will be sufficient to meet all of the demand for industrial alcohol and at a price that the molasses-alcohol industry cannot meet.

b) The Fischer-Tropsch process for making synthetic gasoline from natural gas or coal can furnish 25 to 35 million gallons of alcohol as a by-product. Here again a price can be arranged so that it will be difficult for molasses alcohol to compete.

c) During the war many industries were forced to use substitutes for ethyl alcohol and found that synthetic isopropyl and methyl alcohols could be adapted to their processes without affecting the product. Since these synthetic products are cheaper than ethyl alcohol and their use is not controlled and regulated by the government, it is doubtful that they will be replaced by ethyl alcohol.

d) Many of the pre-war uses for alcohol have been eliminated. Products, such as acetic acid, acetic anhydride, esters and solvents, which formerly required the use of alcohol in their manufacture can now be synthesized directly from ethylene.

e) Several sugar-producing countries have given indication that they intend to expand their alcohol industries to utilize more molasses in their own country.

f) Further development of processes for utilizing waste substances and farm surpluses for the manufacture of cheap alcohol also offers a challenge to the molasses-alcohol industry.

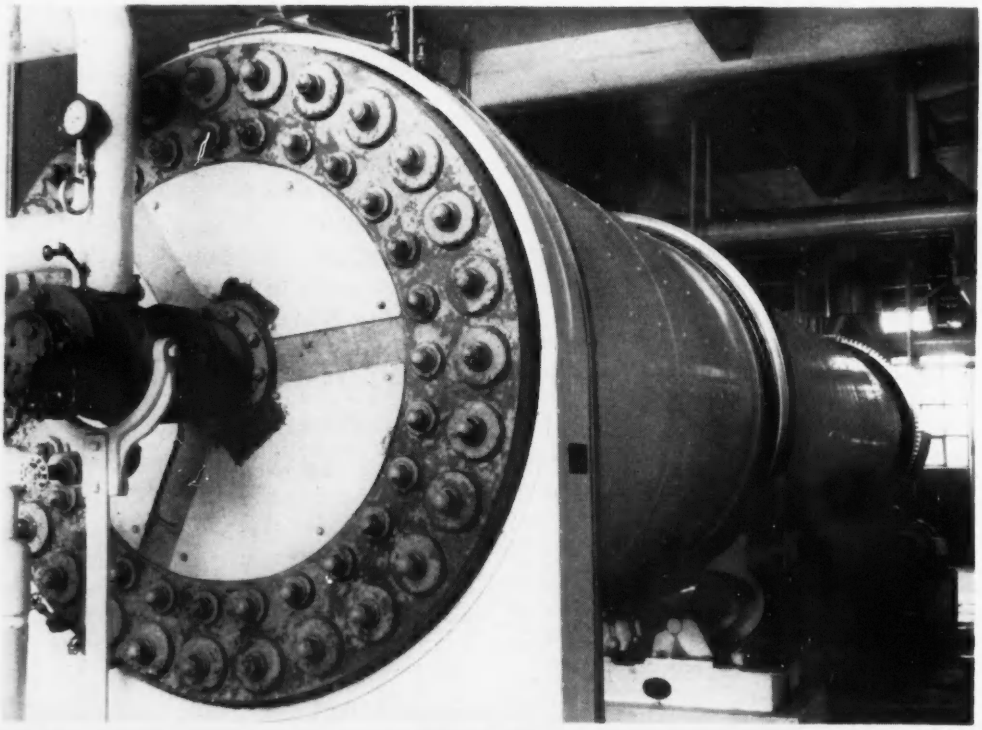
g) The sugar producers have also attempted to stabilize the price of molasses by agreeing to sell at a single price. Thus far this plan has not always worked to their advantage, but it is a factor which must be kept in mind by the molasses-alcohol producers.

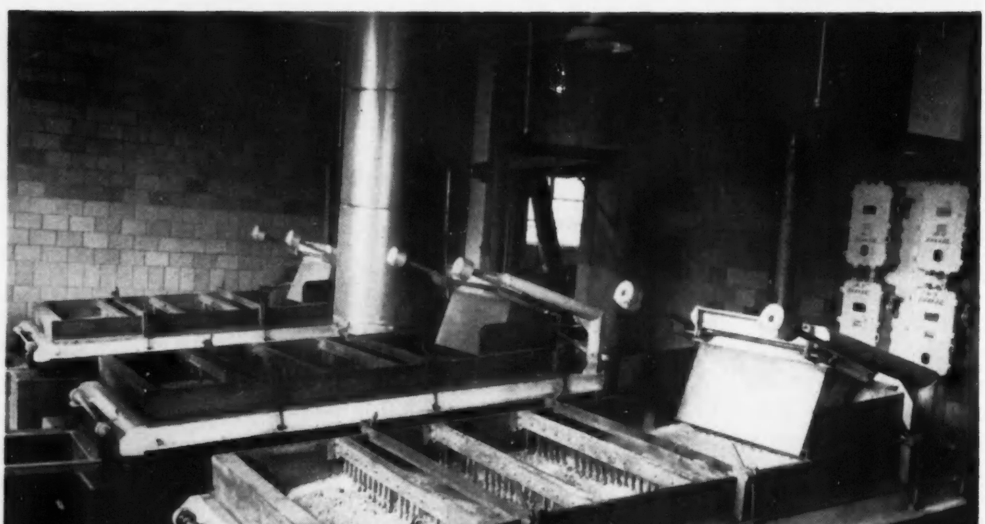
Thus, while the future production of industrial alcohol appears to be more than adequate to meet normal requirements, the amount that will be produced from blackstrap molasses will be dependent upon several factors.

Other Raw Materials

During the last war, when the demand for industrial alcohol increased so greatly, and blackstrap molasses was not available, it was not economically feasible to use only corn to produce all of the alcohol that was needed—despite the fact that corn gave the highest yields. For example, in 1943 the War Production Board estimated the yearly requirements for alcohol at 534,500,000 gallons (95% by volume). This would have required 6,160,000 tons of corn, assuming an average yield of 4.32 gallons of alcohol per 100 pounds of grain. If only corn and malt had been used this would have required approximately 5,600,000 tons of corn. While this represented only a little more than 7% of the total corn crop, corn was needed for animal feed, and there were surpluses of other materials which could be used as raw materials and which were less essential for feeding purposes. Furthermore, there were large quantities of waste materials which were known to be potential sources of alcohol but never had been fully investigated on an industrial scale in the United States. The pressing need for war alcohol now made it advisable to investigate all of these possible sources. Some of them proved to be of major industrial importance, while many others were not developed beyond the laboratory stage.

Wheat. Wheat has been a cultivated crop since long before the beginnings of





recorded history, and carbonized kernels of wheat have been found in archeological diggings dating back more than 6000 years. In the United States wheat culture began with the colonization of the Atlantic coast and was carried westward as the country was settled. Most of the varieties known to the pioneers are no longer cultivated; new and improved varieties have taken their place.

Wheat belongs to the genus *Triticum.* Although as many as 18 species have been described, only a few are important to agriculture. Approximate chemical analyses for wheat are given in Table VII.

ing a surplus of over 800 million bushels. Allowing 300 million bushels for emergencies, there were 500 million bushels of wheat available for industrial utilization despite crop restrictions.

A partial solution to the problem was obvious; by using wheat for the production of alcohol, a surplus commodity could be utilized to alleviate a critical shortage of an essential chemical.

Various types of wheat were tested to determine those best suited for the production of alcohol. White or soft Red Winter, Red Winter subclass, were found to give the best yields; Durum and Hard Spring were unsuitable because of their low starch content; while Hard Red Winter fell between these two groups. The location of the White Wheat and the limited supply of Soft Red Winter made it necessary to use Hard Red Winter Wheat.

TABLE VII

APPROXIMATE ANALYSIS OF WHEAT

	Moisture	Starch[a]	Protein[a]	Ash[a]	Fat[a]
	%	%	%	%	%
Winter Soft White	10.2	64.5	8.5	1.55	1.45
Hard Red Winter Hard Winter	13.0	60.3	11.5	1.49	1.39
Soft Red Winter Red Winter	9.02	62.0	8.6	1.65	1.17
Red Durum	13.0	54.5	13.7	1.73	1.45
Hard Red Spring Northern Spring	13.0	53.0	13.9	1.71	1.50

[a]As received.

Wheat was a surplus grain during most of the last war. From 1941 to 1944 the United States produced approximately one-fourth of the total world wheat crop. Large surpluses accumulated and by 1943 these surpluses became critical. There was a carry-over of 633 million bushels from 1941, and the 1942 crop amounted to nearly 975 million bushels, making a total of $1\frac{1}{2}$ billion bushels of wheat available. It was estimated that the United States would consume 700 million bushels, leav-

Laboratory investigations also showed that a significant amount of non-carbohydrate material could be removed from the wheat kernel and used for food, leaving the carbohydrate for the production of alcohol. Large quantities of wheat were processed in this way by the food

FIG. 5 (*Upper*). Steam heated rotary dryer for drying fibrous portion of residue—to produce Distillers' Dried Grains.

FIG. 6 (*Lower*). Screens for separating dealcoholized residue into fibrous and liquid fractions.

industry, and the by-product, which was designated " granular wheat flour " or " wheat middlings ", was used by the distilleries.

The alcohol yields from wheat, granular wheat flour and wheat middlings were comparable to those obtained when corn was used. There were, however, occasional difficulties in the processing of all three materials which were not ordinarily encountered when corn was used. The nature of the problems differed from plant to plant, depending upon the type of equipment used in processing, the method of cooking and the amount of wheat or wheat products that was used in the mash. Some plants experienced no difficulties at all and operated at maximum capacity, using large percentages of wheat or wheat products; others found it impossible to operate with large quantities of wheat or wheat products in the mash because the fermenting mash foamed so badly that the fermenting vessels could be filled to only a fraction of their capacity, and it was therefore found necessary in some instances either to use less than 50% wheat products in combination with corn or to alter their equipment and method of processing.

Although some granular wheat flour and wheat middlings were used by grain distilleries, these products were handled to better advantage in molasses distilleries. These materials required no milling prior to mashing and there was no need to install equipment for the recovery of by-products, since the solids content of the residue after distillation was so low that it was not economically desirable to recover it for food. That wheat and wheat products were successfully used to produce war alcohol, and were responsible for saving large quantities of much needed corn, is evidenced by the fact that over 240 million bushels of wheat were used to produce alcohol during the years 1942 through 1945 as compared to a little over 120 million bushels of corn used during the same time.

Wheat is commonly utilized in other parts of the world to produce beverage alcohol, but it is not employed to any great extent in this country in normal times. A small amount of beverage alcohol is produced from wheat starch which is a by-product of the wheat gluten industry, but the annual production is relatively small.

Sorghum. Grain sorghums were introduced into the United States less than a hundred years ago. All of the grain sorghums grown in this country are listed botanically as *Sorghum vulgare* Pers., and agronomically, all plants belonging to this species are called " sorghum "—the word being used in the same sense as corn, wheat, oats, etc. However, the varieties of sorghum differ markedly in their characteristics and are used for different purposes. At the present time there are approximately 50 varieties of grain sorghum being grown in the United States.

Sorghum is generally listed as a minor crop in this country, but in many States it has become the major grain crop. For example, in Texas the sorghum yield in 1944 was 28 million bushels more than corn, and 10 million bushels more than wheat; in 1945 the sorghum crop was slightly greater than the corn crop and almost double that of wheat. Texas produced 97 million bushels of grain sorghum in 1944, and 68 million bushels in 1945, as compared with a 38-million bushel average for the ten-year period 1934–1944.

On a national basis the cash receipts for grain sorghums has risen from a little over \$9½ million in 1924 to over \$145 million in 1946. The economic importance of the sorghums is further illustrated in Table VIII.

The scientists of the Agricultural Experiment Stations, who have developed

TABLE VIII

GRAIN SORGHUM PRODUCTION IN THE UNITED STATES[1]

Year	Production (1,000 bushels)	Yield (bushels)	Dollar Value ($1,000)
1937	69,948	14.2	33,917
1940	83,164	13.5	39,942
1943	103,864	15.6	118,201
1944	181,542	19.9	165,712
1946	106,947	15.8	146,571
1947	95,609	17.1	170,446

[1]Statistical Abstracts of the U. S. Dept. of Commerce, 1948.

new varieties of grain sorghum, deserve much of the credit for the increasing economic importance of the crop. These scientists have developed varieties that are resistant to disease, can be harvested by combines, are especially suited to specific conditions of soil and climate, and have specific chemical compositions to meet the demands of certain industrial users.

From 1942 through 1945 over 60 million bushels of sorghum were used to produce war alcohol. The grain sorghum used by the distilling industry was termed " milo ", and in the official grain standards was listed under Class II, Yellow Grain Sorghums, Sub-Class A. In the literature, however, it is not at all uncommon to find milo varieties falling by chance, or otherwise, into other classes of grain sorghums, and, conversely, kafirs and other varieties seem to be classed somewhat freely under the general and all inclusive term " milo ".

Milo compares favorably with corn, as shown by the analyses given in Table IX. The starch content of milo would suggest a potential yield of alcohol at least as good as that obtained from corn; however, the milo that was supplied to the distillers during the war was very dirty and in poor physical condition, and an alcohol yield equal to that from corn could not be expected.

Having had good results with milo during the war, many distillers turned to these same grains for the manufacture of beverage alcohol during the corn shortage after the war. The sorghum producers, however, could not supply clean grain, and the distillers found it unprofitable to clean it before process-

TABLE IX

COMPARISON OF MILO AND CORN

	Milo	Yellow Corn
Chemical Analyses—%[1]:		
Moisture	11.9	9.6
Protein	12.0	8.4
Fat	1.4	2.0
Fiber	2.1	3.2
Ash	1.3	3.0
Starch—dry basis	64.5	63.8
Vitamins—micrograms/gram[2]:		
Riboflavin	1.11	0.93
Nicotinic acid	51.4	25.9
Pantothenic acid	7.0	4.6
Biotin	0.3	0.092
Pyradoxine	6.4	6.9
Alcohol Yield:		
Proof gals./bu.[3]—wet basis (Laboratory)	5.3	5.4
Proof gals./bu.[3]—wet basis (Plant)	4.95	5.09
Dried Grain Analysis—%:		
Protein	28.1	25.2
Fat	7.1	9.0
Fiber	19.0	19.5

[1]Joseph E. Seagram & Sons, Inc.—Research Department.

[2]U. S. Northern Regional Research Laboratory, Peoria, Ill.

[3]50% alcohol by volume

ing, since the price differential with corn was so small; as a result, milo has not been used to any great extent since corn became available.

Potatoes. Both Irish and sweet potatoes were investigated as sources of raw material for war alcohol. There are obvious disadvantages to the use of whole fresh potatoes. Among the more serious disadvantages is the fact that the potato crop is seasonal, with the exception of extremely limited areas in the South where year-around cultivation is considered feasible; in addition, it is a crop that is difficult to store for any length of time. Another disadvantage is that in most cases special equipment is necessary to process the potatoes prior to cooking, and conveying systems must be changed or drastically altered when fresh potatoes are used in a grain distillery. Dehydration of the potatoes is one solution to these problems. This reduces the possibilities of spoilage and results in a product which can be stored and shipped economically; in addition, such a product can be handled in a grain distillery with little or no additional equipment.

Table X presents comparative data for sugar cane, sweet potatoes and corn in terms of crop, carbohydrate and alcohol yield per acre of cultivated land. Average national figures are not used, since it would be illogical to cultivate these crops in areas where they would not be well adapted. The sugar cane yield of 22 tons per acre is the Louisiana average for 1938, reported to be a good year; this is lower than generally obtained in Cuba and Puerto Rico. The 52 bushels per acre yield of corn is the Illinois average by the Department of Agriculture, and 400 bushels per acre for sweet potatoes is a conservative figure based on reports of yields as high as 638 bushels per acre when scientific methods were used. During the war studies were made by the Research Department of Joseph E. Seagram & Sons, Inc., on alcohol production from three varieties of sweet potatoes: a yellow Puerto Rican variety, an important market variety; a variety especially developed for starch processing and cattle feed but not suitable for food use, identified as L-4-5 (Pelican variety); and Puerto Rican culls of the 1942 crop; all were dehydrated. The first two were from the 1943 crop.

All of the sweet potatoes, with one exception, were shredded so that the dehydrated product was in the form of small strips 1/8 to 1/4 inch in diameter and up to 1½ inches long. Milling tests revealed that the potatoes could be milled but that there was an excessive loss due to flouring, and laboratory tests were

TABLE X

COMPARISON OF ALCOHOL YIELD PER ACRE OF CORN, SUGAR CANE AND SWEET POTATO

Crop	Locality	Crop Yield Per Acre	Carbohydrate (Glucose) lbs./acre	Alcohol Wine gal./acre[a]
Corn	Illinois	52 bu.[b]	2,000	147
Sugar Cane	Louisiana	22 tons	6,300	462
Sweet Potato	Louisiana	400 bu.[c]	6,600	497

[a]95% alcohol (assuming 90% of the starch utilized)
[b]56 lb. bushel
[c]60 lb. bushel

made with the unmilled product as well as the milled.

Under the conditions of these experiments the unground L-4-5 (Pelican variety) gave yields of 11.6 proof gallons (50% alcohol by volume) per 100 lbs. with a plant efficiency [1] of 92.5%, while a yield of 11.8 proof gallons per 100 lbs. with a plant efficiency of 94.1% was obtained when the same potatoes were ground. The Puerto Rican potatoes gave a somewhat lower yield, 11.3 proof gallons per 100 lbs. with a plant efficiency of 86.6% for unground potatoes and a yield of 11.2 proof gallons per 100 lbs. with a plant efficiency of 87.3% for the ground product. These mashes consisted of 89% sweet potatoes and 11% barley malt.

Actual plant trials with these two dehydrated potatoes (unground) gave bonded yields [2] of 8.5 proof gallons per 100 lbs. for the yellow Puerto Ricans and 9.9 proof gallons per 100 lbs. for the L-4-5 (Pelican) variety. Laboratory conditions could not be duplicated exactly, and variations in pH were thought to be partly responsible for the lower yields obtained in the plant trials. However, the results emphasized the fact that dehydrated sweet potatoes can be considered a potential source of raw material for the production of alcohol.

Irish potatoes were used rather extensively to produce alcohol during the war. A few distilleries were able to process fresh potatoes with only minor changes in their regular equipment to produce alcohol of beverage quality. Potato spirits have been used rather extensively for many years in certain European countries, but as soon as the grain shortage disappeared in this country, the amount of alcohol produced from potatoes gradually decreased. During the fiscal year, 1949, however, potatoes accounted for 5.73% of the total alcohol produced in contrast to 1.32% in 1948. There were over one billion pounds of potatoes utilized for alcohol in 1949 or approximately five times the amount used for this purpose in 1948. This increased use of potatoes was the result of a large surplus of potatoes from the previous crop which the government made available for alcohol and potato flour at prices which were only a fraction of the support prices. Future use of potatoes for alcohol will probably be dependent upon supply and demand.

Miscellaneous Raw Materials

Many of the plant materials which were investigated during the war as sources of carbohydrate for alcohol production were never developed to the extent of making plant trials. Among these were different types of the oriental and Polynesian taro or dasheen (*Colocasia esculenta* var. *globulifera* (Engler and Krause) Young). In food properties the dasheen is very similar to the potato but contains less water, and consequently the content of starch and protein is about one-half greater than that of the potato. Laboratory studies, however, showed that so long as other materials were available, alcohol could by no means be produced as economically from dasheens as it could from other sources of raw material which were available.

The Jerusalem artichoke or girasole (*Helianthus tuberosus*), a plant native to this country, has been recognized as a potential source of alcohol for many years, and at one time the tubers were utilized to a limited extent in France and Germany for small-scale manufacture of alcohol. Its potentialities for war alcohol were also studied in this country, and a number of investigators found that alcohol production from fresh tubers ranged from 16 to 23 gallons of

[1] Plant efficiency is the percent actual alcohol obtained from the starch present.

[2] Bonded yield is the amount of alcohol obtained for barreling as certified by the U. S. Storekeeper-gauger.

95% alcohol per ton of fresh tubers, representing about 78% of the theoretical yield. However, fresh artichokes deteriorate rapidly, even under the most carefully regulated conditions for storage, and in order to be available for year-around use, tubers must be processed for suitable storage; dehydration seems to be the best method of accomplishing this. Although the fermentable material in the dehydrated tubers is readily extracted by water and can be stored indefinitely, if concentrated and kept covered with carbon dioxide, the general conclusion has been that artichokes are not an economical source of raw material for alcohol production.

Rice (*Oryza sativa*), oats (*Avena sativa*), millet (*Panicum miliaceum* and *Setaria italica*), cassava (*Manihot utilissima* and *M. palmata*), Bassia flowers (*Bassia latifolia*) and practically every other known material containing starch or other fermentable material has, at one time or another, been investigated as a source of raw material for producing alcohol. Some are used rather extensively in specific localities where the supply of raw material is adequate and relatively cheap, while others have remained obscure laboratory material.

Alcohol from Waste Materials

The production of alcohol from waste materials has received its greatest impetus in those countries where coal and oil are scarce or entirely lacking and alcohol is necessary for fuel—such as Germany and the Scandinavian countries. During the last ten years, however, the problem of utilizing waste materials for the production of alcohol has received more serious consideration in this country than ever before. Several factors have contributed to this growing interest in waste utilization, including the following:

a) Increased use of petroleum products, which has directed more attention to the possibility of eventually depleting natural oil reserves.

b) Increased demand for alcohol during the last war.

c) More rigid enforcement of laws dealing with the pollution of streams by industrial wastes.

d) Economic advantage of utilizing waste by-products.

Among the waste materials that have been investigated, or are already being utilized, are fruit culls and cannery waste; grape culls and pomace; and sulfite waste liquors from the wood pulp industry; all of which create a serious disposal problem. In addition, there are the untold amounts of wood waste from the lumber industry; corn cobs and fodder waste from the farms; and many other waste materials containing cellulose which could be converted into alcohol.

Although laboratory and pilot plant investigations, and in many cases actual plant operations, have shown that alcohol can be produced from all of these waste materials; in almost every case the limiting factor which has determined the economic feasibility of industrial production has been the availability of the waste material. The amount of fermentable material that is available, or can be made available, in most instances is relatively small, and large quantities of the waste substance are required for each gallon of alcohol produced. Therefore, the waste must be very inexpensive and in close proximity to the sight of processing; even a few cents transportation charge may spell the difference between profit and loss. Consequently, utilization of these waste materials on a large scale will undoubtedly be limited unless: (*a*) the government passes legislation requiring a certain amount of alcohol to be added to petroleum fuels; (*b*) the demand for industrial alcohol eventually exceeds the amount that can be produced from present raw materials; or (*c*) the government subsidizes the production of alcohol from waste materials.

Waste Sulfite Liquors. Production of

alcohol from waste sulfite liquors is not new to the United States, having been introduced into this country in 1914 from Sweden. Sulfite waste liquors are a by-product in the manufacture of wood pulp and present a serious disposal problem for the industry. The liquors contain a low concentration of fermentable and toxic substances, but the amount is sufficient to warrant many States to prohibit their disposal in streams, in which case the pulp producers must furnish their own disposal grounds. Nevertheless, the industry has been reluctant to dispose of these waste materials by utilizing them as a source of alcohol; there are several reasons for this:

a) The amount of available fermentable sugars is very low and, therefore, provisions must be made for large fermentation vessels if a profitable yield of alcohol is to be realized.

b) The toxic materials, especially sulfur dioxide, must be removed and a nitrogen supplement added before yeast can grow and produce alcohol.

c) The liquors are very corrosive and metal equipment deteriorates rapidly. Recently, however, new metal alloys have been developed which give promise of solving this problem, and it is possible that the pulp industry may now be more interested in utilizing their waste product to produce ethyl alcohol.

FIG. 7. View of warehouse where whiskeys are stored for aging.

During World War I a distillery, having a capacity for fermenting 100,000 gallons of waste sulfite liquors a day, was constructed at Mechanicsville, New

York. By 1920 this plant was producing 200,000 gallons of alcohol annually, but the plant soon stopped operations. A number of improvements were made in the process and a plant was built during the last war at Bellingham, Washington, which began producing alcohol in March, 1945. This was the only plant in the United States producing war alcohol from sulfite waste liquors. The plant continued to operate at full capacity after the war and in 1948 was producing 9,500 gallons of 95% alcohol per day—making available for the first time, to the Pacific Northwest, large quantities of locally produced industrial alcohol.

A sulfite liquor alcohol plant was also built and operated at Ontario, Canada. It also was successful and showed that under certain conditions alcohol produced from waste sulfite liquors might compete with alcohol from molasses.

In the United States waste sulfite liquors offer a potential annual production of approximately 40 million gallons of alcohol. The price of this alcohol could be kept comparatively low and offer real competition to alcohol produced from molasses, since it originates from a waste material that must be disposed of at a price, and, therefore, a part of the alcohol production cost could be assigned to disposal cost.

Wood Waste. The first plants in the United States to produce alcohol from wood waste were operated in Louisiana and South Carolina during the first World War. They used a process now obsolete and ceased operations soon after the war. The German Scholler process, which is the basis for most of the present day plants, began in the laboratory in 1923, and by 1935 several large plants had been constructed in Germany and were producing approximately 2½ million gallons of alcohol per year. These same plants, and perhaps many others, undoubtedly played a significant role in Germany's ability to maintain her military machinery during the last war.

The Scholler process was investigated in this country as a means of producing cheap war alcohol. Some improvements were made in the process and a plant was under construction in Oregon when the war ended. The project was temporarily halted but later was completed, and the plant was operated for a short time after the war. Although many mechanical difficulties were encountered during operation, the feasibility of producing alcohol from hydrolyzed wood wastes in this country was definitely established. The plant has remained idle since 1947, but it is believed that it may yet prove to be of significant commercial value to the Pacific Northwest through the utilization of wood waste for the production of alcohol or wood sugar molasses.

Fruit Wastes. Laboratory investigations undertaken jointly by the Washington State Institute of Technology and Joseph E. Seagram & Sons, Inc., have shown that alcohol can be produced from most fruit wastes, such as cull fruit and fruit cannery wastes. There are, however, certain problems which must be overcome before it will be profitable to produce alcohol from these materials. The amount of sugar varies considerably, depending upon the fruit, and in a few instances this amount is so small that the fruit cannot be used. In almost every case the amount of sugar is relatively small; therefore large quantities of material must be fermented to realize a profitable yield of alcohol. It is not economically feasible, with the present alcohol market, for each cannery to have its own distillery, and mobile distilling units, which could be sent to different canneries, are not adaptable because all canneries within a given area are operating simultaneously and the raw material cannot be stored for any length of

time. Consequently, until these difficulties can be solved economically, it is doubtful that fruit wastes will be used to any great extent for the production of alcohol.

Summary

Any carbohydrate material which contains fermentable sugars or can be converted into fermentable sugars is a potential source of ethyl alcohol. During normal times, however, the beverage alcohol industry in this country continues to rely upon corn, barley malt and rye as a source of fermentable material, while the industrial alcohol fermentation industry continues to depend upon blackstrap molasses. This does not mean that some of these raw materials may not be supplanted by other sources sometime in the future.

It is recognized that the distilling industry consumes only a small percentage of the grain harvested in the United States, but since the industry pays premium prices for grain which meets its specifications, this small amount, when added to that used by other industries, becomes an important factor in determining the overall value of the nation's grain crop.

Research conducted by the more progressive members of the industry has done much to stimulate interest in crop improvement, such as the development of grains with higher starch content, greater enzyme activities and greater yields. Although not all of the improvements sought by the distillers have been realized, the grain producers have received premium prices for growing those crops which have been improved for distillery use, and the value of the national grain crop has been increased accordingly.

Studies to determine the alcohol potentialities of materials other than those normally used by the distilling industry have been made for various reasons: to find new, cheap sources of alcohol; to develop new types of beverages; to utilize surplus crops; to utilize waste materials; or just to satisfy curiosity. Whatever the reason, and whether such studies are translated into industrial utilization or remain obscure laboratory experiments, all of these investigations have added materially to the basic knowledge of alcohol fermentation. The industry will continue to investigate potential sources of alcohol—and when the opportunity presents itself, will utilize these new sources on a commercial scale.

Utilization Abstract

Attar of Roses. This perfume is produced to some extent in France, Germany and Persia, but the bulk of the world's supply comes from Bulgaria where rose gardens cover the northern portion of the old Turkish province of Eastern Roumelia and center around Kasanlik and Karlova. It is a form of *Rosa damascena*, the red damask rose, that is cultivated there for attar. "Gathering the roses starts at daybreak, for they lose their odor if a strong sun shines upon them. As soon as gathered they are taken direct to the distillery. The flowers are picked with the calyx, the whole being distilled. Roughly, a thousand roses weigh one kilogram, and a hectare (2½ acres) yields about three million flowers, which yield in their turn about one kilo of the attar, so it takes about one hundred thousand roses to yield an ounce of attar.

"The rose trees are planted close together, forming hedges of fifty to one hundred yards long, with a distance of six feet between the hedges. They reach, when mature, six feet high. The busiest time of the year is in October and November when the plants are divided and planted. In five years the plantations are in their prime, and with good culture they last fifteen to twenty years". (G. Barton, *Gard. Chron. Am. 53: 35. 1949*).

Carob or St. John's Bread

Carob is the large bean-like pod of a handsome evergreen tree of the same name. Containing 40% sugar and 6% protein, it is chiefly used for stock food and is manufactured into various forms of human food. From the seeds comes a valuable gum, in increasing demand in commerce. Carob trees thrive in parts of California without irrigation.

J. ELIOT COIT

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Introduction

It was the conclusion of De Candolle that the carob tree grew wild " On the Southeastern Coast of Anatolia and in Syria, perhaps also in Cyrenaica " (7). Its cultivation began within historic times, and it was introduced into Greece and Italy by the Greeks, into northern Africa and Spain by the Arabs.

Commercial culture of the carob is distributed more or less generally throughout the Mediterranean Basin, but is limited almost wholly to warm sections near the coasts and to the islands of the Mediterranean Sea which are particularly adapted to its culture. It is also grown to some extent on the Atlantic coasts of Portugal and Spain.

In all these countries the large pods, rich in protein and sugars, are an important forage crop for all kinds of livestock, besides furnishing considerable sustenance for man in times of other food scarcity. There is a notion that the " locusts and wild honey " on which St. John the Baptist subsisted during his sojourn in the wilderness were wild carobs (Matthew 3: 4). They have been supposed to have been the " husks " that provided subsistence for the Prodigal Son.

In later times the carob was introduced into the Americas, Australia and other parts of the world where climatic conditions are favorable. Probably the first introduction into the United States was made in 1854 by the U. S. Patent Office. At that time some 8000 plants, raised from seed imported from Spain, were distributed throughout the southern States.

Commercial culture of the carob is now most important in Cyprus, Crete and southern Greece, Sicily, Sardinia and Majorca. In 1930 carob production in Cyprus amounted to 110,437 long tons but fell to 38,555 tons two years later (21). The tree is also grown to a considerable extent in Spain, Portugal, Palestine, Tunisia and Algeria. In other parts of the world, with favorable environment, the carob is commonly grown as an ornamental, shade or avenue tree. Throughout the subtropical belt of California thousands of fine seedling trees are to be seen, as are occasional ones in Arizona and southern Texas.

Botany

The carob (*Ceratonia Siliqua* L.) belongs to the legume family and is the only species in the genus. The Spanish common name is " algarrobo " (from the Moorish), a term which the Spaniards applied to near relatives they found in the New World such as the mesquite (species of *Prosopis*). In Great Britain and the United States the tree and its

fruit are commonly known as " St. John's Bread ".

The carob is a handsome evergreen tree, 40 to 50 feet high, with large compound glossy leaves, each bearing from one to six pairs of thick leathery leaflets which are usually opposite. The flowers are borne in lateral racemes, two to five inches long, arising from the older branches year after year, forming eventually warty excrescences on the bark. Each raceme bears 30 to 50 flowers, only one to five usually setting fruit. According to J. McL. Thompson (3), endogenous buds regularly form below the cork phellogen covering the swollen wens of tissue bearing the massed secondary inflorescences and burst through cortex and cork to form a tertiary inflorescence. These deep-seated buds lie in pockets filled with mucilaginous fluid which frees by digestive action the newly organized bud meristem from surrounding cortical tissue.

In California the season of bloom extends from September through December and sometimes later. The majority of carob trees are dioecious, a recent count of some seedlings showing a ratio of 18 staminate to 13 pistillate, and none monoecious. However, occasional monoecious seedlings are found and some well-established varieties are monoecious.

In the staminate flowers the calyx tube is disk-bearing, the segments of the disk being five in number and short. There are normally five stamens. In the pistillate flowers the short curved pistil proceeds from the center of the disk, the tip being enlarged and somewhat lobed. Perfect flowers have both stamens and pistils on the same disk. Pistillate flowers develop into flat indehiscent pods, three to twelve inches long, one-fourth to three-eighths inch thick, filled with a sweet pulpy substance in which are embedded five to 15 obovate, transverse, brown, bony seeds about one-fourth inch wide. The usual season of ripening in California is October and November. Many ripe pods fall naturally, but some remain on the tree several months unless gathered.

Since the carob is a legume, it has been presumed that tubercle-forming nitrogen-fixing bacteria inhabit the roots. So far no satisfactory evidence of this has been found by the writer. The large snake-like roots penetrate the soil extensively, both vertically and horizontally, thus reaching adequate moisture reserves. Production of fibrous feeder roots is scanty in the upper layers of the soil.

Climatic Requirements

The mature carob tree is somewhat more resistant to cold than the orange. Young plants are more tender, and when set in the open field where temperatures near the ground may be expected to go as low as 25 degrees F., should have protection by wrapping with tules or cornstalks. It has been observed that young seedlings vary widely in frost resistance. The relative hardiness of budded trees of different varieties is not yet completely known. The tree blooms in the fall, and immature fruits withstand winter temperatures as low as 20 degrees F.

While the carob is quite drouth-resistant and does well on non-irrigated lands, the size and quality of crop are usually proportional to the amount of effective rainfall up to an optimum of about 23 inches a year average. It is questionable whether profitable crops can be grown in a semi-arid environment on less than an average of 12 to 14 inches. Where rainfall is below 15 inches, good crops will depend on a soil and planting arrangement calculated to prevent or control runoff. Soil moisture is conserved for the trees by preventing the growth of all competing plants. However, it should be emphasized that the drouth-resistance of mature carob trees

is so marked that they remain alive and healthy during several consecutive seasons of sub-normal rainfall, though yielding smaller crops. In this respect they closely resemble the olive.

On the other hand, the carob suffers from too much water, as is attested by the sickly condition of trees planted in wet places, or in lawns which are frequently sprinkled. Wherever it is practicable to provide enough irrigation water to compensate for lack of rainfall, excellent crops can be produced. One of the most important areas of dry-farmed carob production in the Old World is on the island of Cyprus, where the average annual rainfall is 20.43 inches. At Murcia, Spain, the carob is grown extensively with an annual rainfall of 14.50 inches. In the carob plantations of Tunis, the rainfall is 16.50 inches. However, Nouri states that in Cyprus an average rainfall of 12 inches registered during the winter months (November through February) should be considered as satisfactory for good bearing of carob trees (12).

The carob requires a near-rainless autumn when the pods are reaching maturity. Ripening occurs in September and October, according to variety. Harvest is in October and November. Early fall rains of short duration do little or no harm, especially if followed by drying winds. A protracted wet spell after the pods have reached a high sugar content is likely to cause loss of quality by moulds and fermentation. Near the coast in southern California, particularly in the fog belt, carobs often mould at maturity and are quickly infested with worms. In Mediterranean countries carobs are grown quite near the sea; in fact, one European writer states that carobs thrive on "exhalations of the sea". In the coast towns of California the carob is quite popular as a street tree, but its commercial culture is not recommended for the fog belt.

The chief carob districts of the world are characterized by warm dry weather in late summer and fall. The foliage is quite tough and very resistant to hot winds. Where irrigated, the tree thrives in regions of intense heat, such as the Coachella and Imperial Valleys of California, and the Salt River Valley of Arizona. Thrifty specimens growing as avenue trees with some irrigation may be observed at Indio, California, and Phoenix, Arizona. So far as known, no orchard test has been made in American desert areas. Since before the time of Christ the carob has been grown in Palestine, although, according to Oppenheimer (13), on hot dry "khamsin" days temperatures may range as high as 104 to 122 degrees F., with relative humidity as low as six percent.

Soil Requirements

Carobs grow and thrive in many types of soil. They prefer a deep rather heavy loam which has good sub-drainage. While limestone soils are especially favored, a high pH is not essential, as shown by many thrifty trees in southern California on moderately acid soil. Where soil conditions permit, the root system extends to great distances, both laterally and downward. Roots 60 feet long have been measured and recorded. This strong root system, capable of drawing soil moisture from great distances, coupled with the semi-xerophytic character of the leaves, accounts for the low water requirement of the species.

On Mt. Scopus, Jerusalem, the root system is limited to the shallow soil stratum covering the limestone rocks. The transpiration rate is low, as are also the osmotic values. In comparison, the almond is a water spendthrift (14).

Carob trees grow and fruit heavily with no fertilization. That they would bear sufficient increase to warrant fertilization is yet to be demonstrated. Some European writers state that it is re-

garded as a waste of money to apply fertilizer to carob trees. However, it is the experience of the writer that the addition of one pound of sulphate of ammonia to each 400 gallons of water used to basin-water the young trees the first summer after planting stimulates growth and sets them off to a better start.

FIG. 1. Seedling carob tree as an avenue shade tree. West Los Angeles, Calif.

In the Old World the carob is grown to only a very limited extent in regular orchard formation, and then usually in combination with grapes or other intercrops of small stature. It is more commonly regarded as a waste-land crop, occupying the more or less stony slopes above the irrigated plain. Such areas are generally used for pasture. The trees springing up naturally are grafted in place, and much of the crop is eaten by livestock as it falls (17). Under such conditions statistics on yields are not reliable. It cannot be emphasized too strongly that such a system of culture would ensure failure in the American Southwest. There the chief pest is the pocket gopher which is especially fond of carob roots. Success with carob in pastures would depend on ridding the land of gophers and keeping them under close control thereafter. Inasmuch as livestock is fond of carob leaves, an orchard cannot be pastured until the trees are tall enough to be beyond reach. In Cyprus volunteer seedling thickets make good goat pasture, where continuous browsing keeps the plants in low bush form.

In California the carob not only requires but deserves good average hay and grain land where erosion control is practicable and economical, and where rodent pests can be effectively controlled. As with citrus, walnut and fig culture, any carob industry in the United States should be characteristically American in spirit and new in methods. European precedents and practices should be largely ignored in developing carob culture under the very different conditions obtaining in America.

Cultivation

Cultivation of the soil of properly contoured carob orchards serves no useful purpose except to control weed growth which competes with the trees for soil moisture. However, at a greater initial expense, weeds can be eliminated by oil or herbicidal sprays.

There are no experimental data with respect to possible benefit to the trees by growing and turning under a winter cover-crop, as is done with citrus. The thrifty condition of many old trees growing on streets and surrounded by pavement indicates that the need for humus in the soil is small. While the rainwater consumed by a cover-crop, and the cost of growing it, would seem not to be economical, the question cannot be answered finally without further experimentation.

There are many thousands of acres in the semi-arid Southwest which, because of limited water supply, can never have the benefit of irrigation. Much of this land has been ruined by erosion due to ignorant or careless dry-farming operations. Much more is in process of being ruined. Within recent years the formation of soil conservation districts has resulted in increased public interest in safeguarding the soil. This should be encouraged. Heretofore the chief hindrance to progress has been lack of appreciation of the dire results of soil erosion for the country as a whole; and the fact that proper soil conservation measures cost money. In recognition of the latter, our government now offers some financial and supervisory assistance to land owners who will agree to carry out programs approved by district engineers.

The carob is a beautiful evergreen tree which, in suitable situations, offers a profit motive for soil conservation by erosion control on dry lands. It is capable, when in bearing, of producing several times as many units of livestock food as barley or hay, and at less annual cost per acre. The chief hindrance is the cost of establishing the orchard and lack of income during the time the trees are growing to bearing age. On the other hand, there are worthwhile inducements. These are: the supervisory and financial assistance mentioned above, the appreciation in land condition and value, cost of trees may be deducted from taxable income and operating expenses thereafter, and the prospect of much greater eventual income from both livestock feeds and manufactured products.

Propagation

Seeds, when collected from recently ripened pods, germinate readily. When seeds dry out they become flinty hard and are very slow to germinate unless rubbed on sandpaper or soaked till they swell. Some nurserymen soak the pods for two days and then plant them without removing the seeds. In any case an excess of seeds should be planted, as many may be very slow in germination. Seeds may be planted in beds or flats in clay loam soil, and when the second set of leaves is well formed, the seedlings are planted in small pots or tar-paper containers. When four inches high the plants are shifted, without disturbing the roots, to wooden or tar-paper containers four by four by 12 inches deep. When the seedlings have developed a stem

three-eighths inch or more in diameter four inches from the soil surface, they are budded in the conventional way. Budding should be done as soon as the bark slips in the spring. Buds are selected from strong upright twigs, about six inches back from the growing tip. They are cut with a shield at least one and a half inches long. After insertion, sprinkled water should not come in contact with the buds. After healing in, the stock is cut back part way to start the buds. As the buds grow, it is further cut back by degrees. The containers should be moved from time to time to prevent the tap-root from growing into the ground.

Because of few small or lateral roots the plant is difficult to transplant and handle with bare roots as is customary with deciduous fruit trees. Bare-root carob trees nearly always fail to grow. Therefore when planting in the field the plants should be shifted from the containers without disturbing the roots. Seedlings may be set in the field and later budded in place, but this is more expensive and troublesome. Old carob trees may be easily grafted (top-worked) by the usual methods. Indeed it is common practice in the Old World to topgraft seedlings which spring up naturally from seeds that have passed through livestock and been dropped in pastures. Some European farmers who prefer dioecious pistillate varieties make a practice of grafting one limb in each or alternate trees to a staminate variety for the sake of better pollination.

European writers state that the carob will root from cuttings. Experience of several nurserymen in southern California is that it is possible when hormones and bottom heat are used, but even then it is not easy. Furthermore the root systems formed by cuttings are inferior to those formed by seedlings.

When grown in orchard form the recommended spacing of trees is 30 by 30 feet. An earlier income will result if trees are double set 15 by 30 feet. Alternate trees should be removed at ten years of age or before they crowd and rob each other of soil moisture.

Pruning

For the first few years carob trees are prone to send up many suckers from near the ground. It is necessary to keep all of these cut off while young and before they detract from the main trunk. The tree usually forms a good head without training. In later years little pruning is needed beyond occasional removal of interlacing or broken branches.

Varieties

There are numerous fine varieties of carob in Europe. Some are prized for human consumption, but most of them are used for stock food. Notable among these are the Roja Vera, Nacho, Castellano and Bravie of Spain; the Amele of Italy; the Habati, Thehawi and Sandalaui of Palestine; the Banturia of Crete; and the Apostoliki and Tillirisimo of Cyprus. The last-named variety is reputed to be of finest quality with exceptionally high sugar content. The quality of any variety varies considerably, depending on the environmental conditions where grown.

The proportion of fiber, flesh and seeds varies widely among varieties. The United States Department of Agriculture has made a number of importations of bud-wood but few of them have become established. So far as known only two varieties from European buds have survived; one large budded tree at the George Roeding old home place east of Fresno (now owned by W. H. Everett), and five large budded trees at the Huntington Botanic Garden at San Marino, California. The latter are thought to be Roja Vera from Spain, but accurate records are not now available. Neither of these appears to be of outstanding

quality. Renewed efforts are now being made to introduce some of the finest varieties from Europe.

In the spring of 1950, through the cooperation of the U. S. Department of Agriculture and the University of California at Los Angeles, budwood of improved varieties was received from Tunis, Greece, Cyprus and Italy. Of these, 13 trees representing five varieties are now well established. Some buds grew three feet high in six months in dry soil without any rain or irrigation.

Varieties of California origin which have been named and propagated to some extent are Bolser, Excelsior, White, Santa Fe, Victoria and Anaheim. Of these, the Bolser is superior and the only variety propagated during recent years. Several new and promising seedlings, such as the Horne and Nichols, are under test. Planting of the Bolser has so far been limited to yards and gardens and a few street plantings. It has not been tested in orchard form. Bolser is an hermaphrodite with plentiful pollen-bearing flowers mingled with female flowers.

Most ordinary pistillate seedling trees, as found growing on our streets, produce pods of such poor quality as to be practically worthless. Most of them are just seeds and shuck, with very little flesh and sugar. Therefore any carob orchard to be a success must be planted with trees budded to improved varieties well suited to our various uses. It may be that in time two or more varieties will be needed, one for stock food and the other for seed to be used in manufacture of the various products obtainable from the seeds. In the latter case, the remainder of the pod, consisting mostly of sugars, and the germ of the seed with its high protein content would be available as a fattening food for stock.

Harvesting

Carob pods mature and turn dark brown in September, the Bolser being ready for harvest but still containing some 20% moisture in early October. The first rains may usually be expected the latter part of October, hence that is the principal harvest month. Failure to get the crop into storage before rains does not necessarily mean loss of the crop, but may result in a depreciation in quality depending on the variety, the length of the rainy spell and the kind of weather following.

Harvesting is very simple. Large sheets of tent cloth are spread under the trees and the ripe pods shaken down. A light pole is used to knock down any remaining pods. Most pods will be dry and hard, but some may still have green ends. Hauled to the drying yard, they are graded according to dryness. Those showing green ends may be spread in the sun for a few days. Carob is attractive to weevils and the usual insect pests which infest stored grain and dried fruit. If to be kept for any length of time, it should be stored in a dry well-screened and rat-proof storehouse. If the pods are to be broken or reduced to powder in a hammer mill, they should be quite dry, otherwise they will gum up the mill.

Yields to Be Expected

European literature abounds with references to individual trees which yield large crops, even as much as 3,000 pounds. It is of course possible that a large and old isolated tree, with its roots within reach of some water other than rain, might produce such a crop. It would be the height of folly to estimate expected yields by multiplying any such yield by the number of trees per acre. It is important to remember that unirrigated carob is rather slow to come into bearing, but there should be an annual increase in yield up to 25 or 30 years. While there are no commercial orchards in bearing in the United States from which figures on actual yields may be had, it is possible to arrive at fairly reliable estimates from the many street

FIG. 2. Carob pod, foliage and pistillate flowers. Natural size.

and yard trees now in bearing. Some years ago the writer was employed for several weeks to examine the quality of pod and tree yield of all the old street trees to be found in several southern California towns. The purpose was to search for an even better variety than Bolser. The yield of a great many trees growing under diverse conditions was noted, and in many cases measured. The estimate of average yields given herewith is based on the personal observations of the writer over a period of more than 25 years.

The carob tree, under favorable dry-farmed conditions, should begin to bear the fifth year from budding and produce an average of five pounds per tree. The size of crops will increase gradually, reaching an average of 100 pounds the twelfth year. Additional increase may be counted on till the trees are full grown, or the 25th year when, in good crop years, an average yield of 250 pounds may be attained. With trees planted 35 feet apart, or 35 to the acre, the expected yield of 8750 pounds is much more than can be counted on from barley or hay under similar conditions.

That the above estimates are conservative is indicated by the following from the late Aaron Aaronsohn of the Jewish Experiment Station in Palestine: "In Palestine carob trees at 18 years of age from grafting yield 450 to 550 pounds" (1). In Tripoli the tree begins to bear at ten years and yields an average of 44 pounds; 110 to 165 pounds at 25 years (21). Nouri states that in Cyprus carob trees produce the first fruit (about three pounds) the third year from budding; at ten years, 85 pounds; and 280 pounds at 30 years. Exceptional individuals may produce as much as 2000 pounds in one year. The trees are alternate bearers, a heavy crop being followed by a light crop. A good general average for all trees for a series of years is 126 pounds (12). Anagnostopoulos states that in Crete carob is grown principally on hilly rocky land where no other culture will grow. He gives average yields at from 25 to 50 pounds, with occasional trees yielding as much as 150 pounds.

It has been noted in California that without water other than rain, carob trees bear large crops after years of heavy rainfall and light crops after a series of seasons of below normal rainfall. However, the trees are remarkably resistant to drouth, and although yielding light crops after a severe drouth, survive a series of dry years in excellent condition.

Pests and Diseases

The most important pest of carob trees in America is the pocket gopher (*Geomys bursarius*). This ubiquitous burrowing rodent is especially fond of carob roots and is the chief cause of failures which occur in roadside plantings. Rabbits and ground squirrels also may cause damage to very young trees unless the trees are protected by wire netting. Cattle are fond of carob foliage, and an orchard cannot be pastured until the trees grow tall enough for the bearing branches to be beyond reach. Occasionally deer may damage young trees which do not have the protection of modern deer-repellent spray.

In Europe several insect pests are reported. The carob moth (*Myelois ceratoniae* Zell.) attacks the pods, both on the tree and in storage. The ivy scale (*Aspidiotus hederae* Vallot) is not uncommon. A boring beetle (*Cerambyx velutinus* Brull.) attacks the tree trunk. Carob midge (*Asphondlylia gennadii* March.) causes stunting of the young pods.

Scale insects reported by Gennadius in Cyprus are: *Lecanium* sp., *Lepidosaphes* sp., *Aspidiotus ceratoniae* and *Aonidiella aurantii* Mask. (8).

In America the only insect pest worthy

of note is the red scale (*Aonidiella aurantii* Mask.), but so far it does not build up on carob trees to a point justifying treatment. No damage has been seen, even when growing adjacent to infested citrus orchards which require control treatments. So far no fungus disease of any importance has been reported in California except mould of the pods in the coastal fog belt. In south Texas the cotton-root-rot fungus (*Phymatotrichum omnivorum* (Shear) Dug.) may attack the carob, as it does its near relative the native mesquite (*Prosopis glandulosa* Torr.). This is usually not serious except where soil moisture is in excess, as when old trees are included in a new lawn which is well watered.

In Cyprus fungus diseases cause slight damage. *Cercospora ceratoniae* Sacc. causes a leaf spotting, and *Oidium ceratoniae* Ames. sometimes deforms very young pods.

Geographic Range

By far the most important area in the United States suitable for commercial carob culture is in California. In southern California, south of the Tehachapi mountains, there are extensive areas of unirrigated foothills where soil, rainfall and temperature conditions are ideal. South of Fresno, in the San Joaquin Valley, it is usually too cold at elevations of sufficient rainfall. Northward from Fresno the rainfall increases and a belt of suitable land, very variable in width, runs along the eastern foothills and extends through the Sacramento Valley as far north as Butte County. Of less importance are occasional areas on the western foothills of the Sacramento Valley. Nearer the coast sizable but scattered areas may be found in Sonoma, Napa, Santa Clara and San Luis Obispo Counties.

In Texas the most compatible environment lies in the general area around Uvalde and Carrizo Springs and southward, where freezing northers would only occasionally result in some injury. Occasional carob trees are found in the lower Rio Grande valley. There is an avenue planting about 20 years old at the west end of Polk street in Harlingen. There is also a fine specimen near Mission. In the warmer parts of southern Arizona rainfall is not sufficient and irrigation would be necessary. There the cost of production would probably put carob at a disadvantage in competition with alfalfa as a stock food.

In the southern part of the Gulf States rainfall is high, and lack of a rainless ripening period results in decay of the pods on the trees. Throughout this region occasional carob trees may be found, even as far south as Miami, Florida, but they are not thrifty in habit and the crop is worthless.

In Latin American countries, Hawaii, Australia and other subtropical parts of the world there are scattered areas where carob may be grown commercially, provided the following conditions are met: average rainfall between 12 and 25 inches, a near rainless ripening and harvesting season of three months, and temperatures seldom lower than 20 degrees F.

Utilization

Since ancient times the primary use of carob pods has been the feeding of all kinds of livestock, for which they are well suited. A secondary use has been for human food, especially in times of famine or other scarcity. In southern Greece, during World War II, after the German army had stripped the country of livestock and most other food, the rural inhabitants subsisted largely on carob pods.

Feed for Livestock. The carob is rather low in protein but very high in sugars which are present in varying amounts and kinds. Invert sugar and sucrose occur in differing proportions. Because sugar is an excellent source of

energy, carobs are a good feed for horses doing heavy work. They are also a common feed for the famous horses of Arabia. Sugars in food, not converted into energy, are laid up in fat; hence carob is an excellent fattening food for beef cattle and swine. For dairy cows, milk goats and rabbits the proportion of protein is low, and for them carob meal should be mixed with higher protein feeds. For all livestock carob should be fed together with hay or other roughage.

pounds in 1937 to only half a million the following year; then rising to over a million for a few years, down to 99,000 in 1942 and up to a million again in 1948. Since 1931 the market prices in the producing countries at the dates of shipment have fluctuated from $27.80 per ton in 1932 to $110 in 1947. To these costs must be added the expenses of loading, ocean freight, insurance, brokerage, and unloading at U. S. port to arrive at the value on U. S. docks.

COMPOSITION OF THE CAROB BEAN

Water	Ash	Protein	Fat	Sugars	Nitrogen extract other than sugars	Crude fiber
I. Carob Pod and Seeds Average of eight seedlings, percent						
13.28	2.57	6.75	2.17	30.52	39.80	9.29
II. Carob Seeds Average of six seedlings						
11.74	3.18	16.46	2.50	0	58.61	7.50
III. Carob Pods without Seeds, water free basis Average of 17 seedlings						
...	3.09	5.03	2.62	39.06	40.56	9.78
IV. Horne Variety, Entire, Oceanside, Calif., 1948 Crop						
10.00	2.95	5.88	1.44	30.86	40.09	8.78
V. Bolser Variety, Entire, Vista, Calif., 1949 Crop						
10.00	2.39	5.50	0.53	39.69	33.56	8.33

Data under I, II and III are from citation #10.

Because of its characteristic odor and flavor, carob is greatly relished by farm animals. In feeding experiments with calves at Davis, California, it was found that when mixed with other feeds, carob pods were approximately equal to barley (10).

For the foregoing and other purposes carob pods are imported into the United States duty-free from Malta, Italy, Greece, Cyprus, Portugal, French Morocco and Palestine. The amounts brought in have varied considerably, falling from more than two million

Carob Gum, Manogalactan (Tragasol). Surrounding the endosperm of the carob seed is a layer of gum resembling mucilage in the manner of forming gels. It is a polysaccharide composed of D-galactose (20%) and D-mannose (80%) (16).

Current and potential applications of manogalactan are many and diverse, some of which follow:

PAPER: Beater size, tub size, calendar size, coating.

FOODS: Cheese spreads, ice cream and frozen malted milks, salad dressings,

chocolate milk, mustard, desserts, pie fillings, sausage and sausage casings, bread, French dressing, etc.
TEXTILE: Printing pastes, warp sizes, finishing.
COSMETICS: Wave set lotion, hand lotion, creams.
LEATHER: Finishing, tanning.
PHARMACEUTICALS: Laxatives, pills, lubricating jellies, shaving cream, tooth pastes.
RUBBER LATEX: Creaming agent, thickening agent.
PHOTOGRAPHIC FILM: Emulsions.
MATCHES: Head binder, striking binder.
PAINTS: Water emulsion paints.
INKS: Lithograph, writing.
POLISHES: Metal polishes, liquid automobile polish, liquid shoe polish.
CERAMICS: Binder, plasticizer (bricks, porcelain, tile, pottery).
PETROLEUM: Drilling mud.
ADHESIVES: Mucilage, hand paste ingredient.
MISCELLANEOUS: Sanitary napkins, flotation agents, boiler compounds, insecticides.

In the manufacture of carob gum the skin of the seeds is removed by rollers which turn in opposite directions. This is followed by roasting, boiling in water, filtering, evaporating the liquor, pulverizing and packing the dry gum. The seed represents, on the average, about 10 percent of the weight of the entire pod. A ton of carob yields about 35 pounds of pure dry powdered gum. Carob gum is prepared in different European countries in a variety of manufacturing plants. In 1939 imports of carob seed gum (tragasol) into the United States amounted to more than four million pounds (11); in subsequent years there was a decline in imports, but in 1948 they rose to more than 6¾ million pounds, valued at nearly 1¾ million dollars.

Due to difficulties of importation during World War II, a fairly satisfactory substitute for carob gum was found in manogalactan from the seeds of guar. This annual leguminous plant (*Cynopsis tetragonolobus* Taub.) was grown commercially in Arizona and southern Texas as a field crop. Guar gum differs from carob gum in the proportions of mannose and galactose as follows: anhydrogalactose 32% and anhydromannose 59% (4). The practical value of this difference is still under investigation. While the two gums are interchangeable for some uses and may be considered to a certain extent competitive, carob gum is usually preferred for use in food products.

Human Food. For six or seven years beginning about 1922 there was considerable interest in California in various human food products manufactured from imported carob pods. Some very extravagant claims were made with respect to the health, medicinal, laxative and other properties of some of these products. Some of them seemed worthwhile, however, and the writer made a collection of samples. Carob flour was mixed with wheat flour and a type of bread made which was quite good and sold in some quantity in Pasadena and Los Angeles for several years.

Carob syrup is made by reducing the pods to coarse powder, dissolving the sugars with water and then boiling the solution down to the thickness of honey. Carob syrup has a good color and high flavor and was used for a time. Breakfast foods made by beating the pods without seeds into a powder was sold both as straight carob and mixed with wheat products, according to the amount of fiber desired. This is still sold in many health food stores. Another very attractive product was known as " carob crumb ". This was light in color, very sweet and highly carob flavored, with almost no fiber. Straight carob is too high in fiber for most stomachs. Dioscorides in the first century A.D. praised the carob in his " Materia Medica " as a laxative and diuretic.

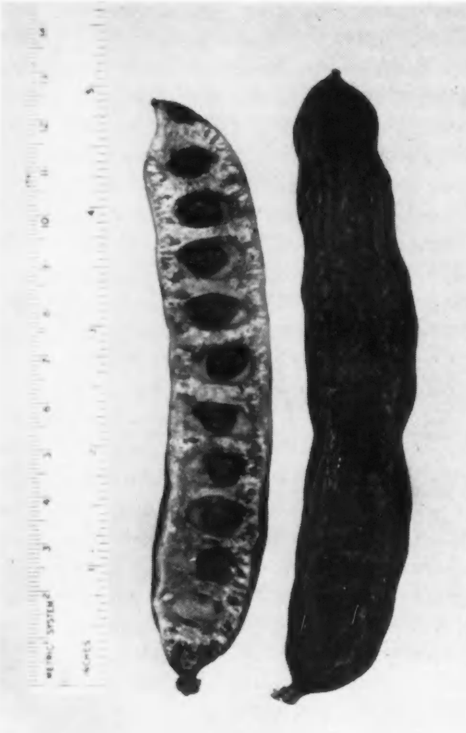

FIG. 3. Fruit of Bolser variety as grown at Vista, Calif. Crop of 1949.

Alcohol. An establishment in Sicily is engaged in the manufacture of alcohol from carob. The sugars are extracted by diffusion in water at a temperature of 95 to 105° C., fermented with selected yeasts, after which the alcohol is separated by distillation (19).

A certain portion of the carob pods imported into the United States is used for human food in the natural state by persons who have been reared in Mediterranean countries where carob is a familiar item. Another portion is used for flavoring chewing tobacco. Carob flowers are a good source of honey, as are the flowers of its near relative, the mesquite (22). In Europe carob seeds are sometimes used in making rosaries.

The wood of the carob tree is not particularly useful except as fuel. It is hard and of high caloric value. On account of the propensity of popping out sparks, both the wood and charcoal made from it are best burned in stoves.

In California the carob has been widely used as a beautiful evergreen shade and avenue tree, for which purpose it is well suited in its younger years. The roots of very large old street trees sometimes cause bulging of sidewalk pavements. Some objection is made to the litter of pods on the streets, but this can be avoided as well as a greater degree of uniformity achieved by using trees budded to staminate varieties.

Economic Status in California

In the years from 1920 to 1925 there was a surge of interest in carob culture. This was largely promoted by real estate subdividers whose principle interest was the sale of unirrigated lands. Not one of the several promotions was adequately financed, and they all failed before any significant amount of carob was produced. So many innocent people lost their money in this way that carob culture acquired very ill repute in the estimation of the general public. As a matter of fact, the carob tree never had a fair chance to demonstrate what it could do under favorable conditions in California. With the passing of 25 years financial wounds have been largely forgotten, and the time is ripe for a rejuvenation of interest in carob culture in California.

Carob culture offers a profit motive for erosion control. When in bearing, the tree will produce several times as many units of stock food per acre as grain and at a lower annual cost. With orchards properly contoured and cared for, erosion is prevented and the land is preserved for future generations. While it is true that the orchard cannot be pastured while the trees are small, it is possible, where necessary, to grow some hay

in the spaces between the rows for a few years. After that the trees will need all the rainfall moisture.

An additional way to increase income in the early years is to plant twice as many trees per acre. Early yields would be double that of a single planting, but alternate trees should be removed by the time they are 12 to 15 years old, when they would rob each other of available soil moisture.

There are some localities in California where, due largely to the increasing costs of orchard heating and for other reasons, citrus culture has been or will be abandoned. Where such acreage may be acquired cheaply, one-half to two-thirds of the water rights may be sold off the land, retaining enough to give carobs one or two irrigations each summer. Under such conditions the trees may be planted closer together. They should develop more rapidly and produce much more than under dry farming conditions.

In many parts of Europe the carob is regarded as a wasteland crop to be used for goat pastures on rocky hillsides. It cannot be emphasized too strongly that such a policy would ensure failure in America.

While any commercial planting of carob in California should be based on soil conservation and domestic animal food, the many other uses previously mentioned may, if properly promoted, result in additional and perhaps substantial values. It should be clearly recognized, however, that the full amount of any higher returns due to manufacturing, advertising and promoting special products, of which there are many, are not likely to accrue to the grower unless he furnishes capital for and controls the manufacturing enterprises.

A Carob Demonstration Orchard

Funds for a four-acre demonstration orchard which was planted in March, 1949, have been provided by Dr. Walter Rittenhouse of San Diego (5). The purpose is a public exhibit of what the carob can do in the way of soil conservation and the production of stock food. The orchard is planted on dry land which has suffered some erosion. The location is on Buena Vista Road, one-fourth mile east of Pechstein Lake, between Vista and Twin Oaks Valley, in northern San Diego County, California. The elevation is approximately 800 feet and the average rainfall about 17 inches. The general public is invited to observe the development of this orchard which is being managed in cooperation with the University of California and the Soil Conservation Service. It is planned for a period of 30 years.

This demonstration orchard is designed to function in several ways. It should show how much tonnage per acre good budded carob trees, well cared for, will produce at successive ages. It will furnish an opportunity to test and compare several local varieties as well as new introductions of the best varieties from Europe. A collection of the best varieties will be maintained for free distribution of bud-wood to nurserymen and others. In the course of time various problems will doubtless arise and this orchard will be available for study and experimentation.

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Utilization Abstract

Pine Breeding. The practical principles of genetics and the techniques of plant breeding have been applied to timber trees, as well as other economically important plants. " Much of this work has been done with pines because of their wide distribution and their value for many wood products. Today pine-breeding research has progressed to the point that promising pine hybrids exist for each of the major timber-producing regions of the United States ".

Work of this nature has been carried out in Europe and Australia, as well as the United States, and involves the traditional techniques of selection and hybridization as well as the newer and as yet little developed " shot-gun methods " of inducing gene mutations and chromosome rearrangements by X-ray and other types of radiation, heat treatment, and cold shocks. " The doubling of chromosome numbers by treatment of seeds or growing points with colchicine, acenaphthene, or other chemicals was once regarded as promising for making pine hybrids true-breeders. This hope has faded somewhat in the face of a number of failures of this type of experimentation, and at present such work is placed in the category of pure research, which, given sufficient time and effort, may yet produce valuable tools for the practical plant breeder ".

Hybrids between native American and foreign species of white pine, as well as between the native species of this group, have all been found to be more vigorous than the parent species, and it is hoped that the resistance of the Balkan and Himalayan pines to blister rust can be introduced into such crosses which display hybrid vigor.

" Pitch pine, which is currently of minor importance in the Northeast because of its poor form and slow growth, has been successfully crossed with loblolly and shortleaf pines to yield hybrids that surpass pitch pine in form and rate of growth. The hardiness of these hybrids has not yet been tested in the more northerly region inhabited by pitch pine, but it is reasonable to expect that the hybrids will be at least intermediate in cold resistance ".

Hybrids involving loblolly, shortleaf and slash pine of the Southern States have shown qualities that may be developed to a useful point, and in the Lake States crosses between jack pine and lodgepole pine have shown great hybrid vigor. And in the West hybrids have been made with Monterey pine, knobcone pine, ponderosa and Coulter pines. Increased growth rate, greater hardiness, improved gum yield and disease resistance are among the objectives in all this breeding work, but the present status of the work might be likened to that of corn breeding in the early 1930's before hybrid seed became available to the farmers. (J. W. Duffield & P. Stockwell, *U. S. Dept. Agr., Yearbook, 1949: 147*).

Utilization Abstracts

Cortisone. In 1949 the highly significant medical announcement was made that arthritis can be effectively treated by injections of a hormone produced in the cortex, or outer layer, of adrenal glands and that this new " wonder drug " may be of value also in treating rheumatic fever, other chronic degenerative diseases, heart ailments, hardening of the arteries, high blood pressure and perhaps even cancer. This drug was named " Compound E " and also " cortisone ", by which latter term it is more commonly known, because of its being naturally formed in the cortical regions of the glands which produce it.

Cortisone is produced naturally in extremely minute quantities, and the natural source of it could not serve as an adequate source of the drug for medical use. In seeking a means of producing it otherwise it was found that it can be obtained synthetically from a component of ox bile, but only in a very complicated and costly set of some 40 chemical stages. Furthermore " if oxen were to be used exclusively in preparing cortisone, the drug necessary for the relief of one arthritic patient for one day would require 40 head of slaughtered cattle, thus for one year 14,660 head. The medicine must be administered regularly, like insulin in diabetes. For the continued relief of the estimated seven million arthritics in the United States, in a single year 100 billion cattle would be needed, or about ten times the entire cattle herd in this country ".

Ox bile, too, thus could not well serve as a commercial source of cortisone, and intense interest and importance were consequently given to the announcement in August, 1949, that cortisone can be prepared in 20 instead of 40 stages from a glucoside, known as " sarmentogenin ", contained in the seeds of certain tropical vines, seeds which presumably could eventually be obtained in great abundance either in the wild or from cultivated plants.

The name " sarmentogenin " was assigned in 1929 by two American chemists, Walter A. Jacobs and Michael Heidelberger, to a new glucoside which they found in about 20 pounds of seed obtained from a commercial source as belonging to *Strophanthus hispidus,* a vine of tropical Africa. No sample of these seeds was retained, but subsequent tests with other batches of seed belonging to *S. hispidus* and to the closely related *S. Kombe* failed to yield appreciable amounts of sarmentogenin. It was thereupon concluded that the first seeds had been mislabeled. Subsequent tests with seeds presumably correctly labeled as *Strophanthus sarmentosus* yielded the glucoside and lead to the conclusion that the original material belonged to *S. sarmentosus,* the specific name of which became the basis for the name of the glucoside.

On the basis of these findings the U. S. Government and some drug manufacturers independently sent commissions to Africa to investigate the possibility of *Strophanthus* seeds becoming a source of the raw material for commercially producing cortisone, and the scientific world awaits their findings.

In the meantime monographic studies on the genus *Strophanthus* have been initiated at the New York Botanical Garden by borrowing over 2,000 herbarium sheets of the genus from about 25 herbaria of the New and Old Worlds. It is hoped that these investigations will help to determine, along with other matters, whether *S. sarmentosus* actually was the species that yielded the original sarmentogenin. The genus has natural distribution only in Africa and Asia, and over 50 species have been recognized, principally woody vines; there are a few erect shrubs or small trees. The vines may climb to the tops of trees 80 feet tall, and the dangling linear corolla lobes may be more than a foot in length, a feature alluded to in the generic name which might be translated as " thong-flower ".

In 1861 David Livingstone, the famous explorer, reported that an extract known as " kombi " from the seeds of *S. Kombe* was used as an arrow poison by natives in East Africa. Subsequent investigations resulted in the isolation, from the African species *S. Kombe, S. hispidus* and *S. gratus,* of a drug called " strophanthin " which has since

been used as a cardiac stimulant similar to digitalis. *S. Cumingii* has been used as an arrow poison in the Philippines, and somewhere in the genus there may be a raw material for the synthesis of cortisone greater than has so far been revealed.

Strophanthus is a member of the Apocynaceae. "Other genera of the Apocynaceae, or Dogbane family, offer possibilities for investigation and some of these are now being tested. *Nerium* (the oleander) is botanically close to *Strophanthus;* its toxic character has been known since antiquity, and it has been, like *Strophanthus*, grouped with the digitalis series of poisons. *Cerbera* and *Thevetia*, of the same family, are also botanically associated with plants having a digitalis-like action. *Acokanthera* contains the glucoside ouabin, said to be identical with G-strophanthin obtained from *S. gratus*. It is reported of *Carisa ovata* var. *stolonifera*, known as 'currant bush' in Queensland, that an alcoholic extract of the bark rapidly killed frogs when injected into them, and that experimental evidence suggests the resemblance of the active principle to strophanthin and ouabin. K-strophanthin-A (a crystalline fraction from the Kombe type of strophanthin) is reported to be identical with cymarin obtained from various species of *Apocynum*. It is not unlikely that from the closely related Milkweed family, Asclepiadaceae, similar medicinal substances may be obtained".

Another substance besides sarmentogenin that has been seriously suggested as a source of raw material for synthesis of cortisone is botogenin, a constituent of yams, discovered and named by Dr. R. E. Marker after several years work on more than 400 species of plants collected mainly in Mexico and southern United States. While *Dioscorea Mexicana* was reported by Dr. Marker to have been the source of his botogenin, this name is not sufficiently precise to give exact identity to the material used. Other genera, scattered throughout the plant kingdom which have received attention in the search for cortisone, have included *Areca, Arisaema, Balanites, Chlorogalum, Digitalis, Lilium, Samuela, Smilacina, Smilax, Trigonella, Yucca* and *Zanthorrhiza*. (Joseph Monachino, *Jour. N. Y. Bot. Garden 51: 25. 1950*).

Since the foregoing abstract was set in type, a sequel article by the same author presents the following significant developments in the search for a vegetable source of cortisone:

1. Professor T. Reichstein and his associates in Switzerland have established from botanically authenticated material that the seeds of *Strophanthus sarmentosus* do not yield sarmentogenin in appreciable quantity. This makes it almost certain that the seeds from which sarmentogenin was originally extracted were not of *S. sarmentosus* and that all attention to that species as a possible commercial source of raw material for synthesis of the drug has been misdirected, unless, as seems very unlikely, "a variety of the species, or material from some removed area, or seeds collected under different conditions of growth or hybridization, may still reveal *S. sarmentosus* as the promising plant".

2. A sample of the seeds from which Jacobs and Heidelberger isolated sarmentogenin the second time and regarded by them as correctly labeled *S. sarmentosus* has been received at The New York Botanical Garden. They were originally obtained by Jacobs and Heidelberger through Dr. J. C. Munch from Dr. H. H. Rusby who collected in South America and are an exact match, morphologically and anatomically, with other seeds, labeled *S. hispidus* by Dr. Rusby and deposited by him in the Economic Museum of the New York Botanical Garden. The genus *Strophanthus* is not known to grow naturally in South America, however, and it is not said that Rusby acquired those seeds there; he merely supplied them and made no mention of the genus in his field notes.

These facts and others discussed in the article make it clear that it was not *S. sarmentosus* from which sarmentogenin was originally extracted and that it is not yet definitely known what the plant was.

3. In the meanwhile Dr. Reichstein and his co-workers have demonstrated that the seeds of two authenticated species of *Strophanthus*, among eight already tested by them, namely, *S. Courmonti* and *S. Gerrardii*, can yield an appreciable amount of sarmentogenin. (J. Monachino, *Jour. N. Y. Bot. Gard. 51: 233. 1950*).

BOOK REVIEWS

Evergreen Orchards. William Henry Chandler. 452 pages; illus. Lea & Febiger. 1950. $6.

In 1942, after serving as Professor of Horticulture at the University of California for 20 years, Dr. Chandler produced a book, "Deciduous Orchards", and in 1950, as Professor Emeritus, he provided this companion volume. The same authoritative treatment pervades this second contribution, and the illustrations are especially worthy of favorable comment. The first 112 pages are devoted to general considerations of evergreen orchards, and the remainder of the book takes up the individual fruits.

Ninety-five pages cover citrus fruits, not only the better known—lemons, limes, grapefruits and oranges—and the lesser known—citron, pummelo and kumquats—but also those that are still less known—Australian desert lime, trifoliate orange, *Microcitrus*, bael fruit, wood apple and white sapote as well as the hybrids rangpur, kusaie, calamondin and limequat. There are chapters on avocado, on papaya and other species of the same genus, on mango, cashew, olive, date, bananas and the coconut and African oil palms. Evergreen nut trees, which are cultivated to some extent in certain parts of the world, are the Australian nut (*Macadamia*), pili nut (*Canarium*), Brazil nut (*Bertholletia*), sapucaia nut (*Lecythis*) and souari nut (*Caryocar*). The litchi and its relatives, longan, pulasan and rambutan, occupy one chapter, and another is devoted to the beverage plants—tea, coffee and cocoa. Nearly three dozen other kinds of evergreen fruit trees of tropical and sub-tropical culture occupy the remainder of the book which, in the words of the preface, "is not concerned much with orchard and packing house practices" and which "is not written primarily for students who are specializing in subtropical or tropical horticulture. It is written with the hope that all good students of tree horticulture will want to see as much of the world as possible through their special field of study, and become acquainted with as much different tree behavior as possible".

Tree Crops. J. Russell Smith. x + 408 pages; illus., 2nd ed. Devin-Adair Co. 1950.

Most books on economic botany are primarily descriptive, and greater utilization of the plants considered in them is more implied and presumed than advocated. Tree Crops is different in this respect, for it not only is descriptive of many economically important trees and of their fruits but has been written for the express purpose of advocating more extensive planting and greater utilization throughout the world of certain food-producing trees that have demonstrated their merit, some for centuries, in limited areas of the world. The author is not a plant scientist but Professor Emeritus of Economic Geography at Columbia University. In his travels over many parts of the world he became so impressed by the soil-destroying effects, particularly on hilly land, of conventional agricultural practice based on annual crops, and by the avoidance of this destruction in a few areas where perennially producing trees are planted instead, that in 1920 he produced the first edition of this book. In this second edition he has incorporated some more recent data and has furnished a volume that provides most interesting reading with a definite message urging greater utilization of certain fodder- and human food-producing trees.

Among the fodder-producing trees the author begins with mesquite (*Prosopis chilensis*), known also as "algaroba", which is native in semi-arid regions over an enormous area of the New World, from southwestern United States to Patagonia. At the northern end of this area, at least, its pods have served as food for various Indian tribes and for the horses and cattle of many a prospector. Some years ago this species was introduced into the Hawaiian Islands where it is known as "keawe", and has since become very widespread there as a result of livestock feeding upon and distributing the pods. Hundreds of thousands of bags of the beans have been picked up in one year in Hawaii, and at one time, at least, the algaroba bean industry in the Islands amounted to several

hundred thousand dollars annually. Years ago the pods were shipped to Japan as food for cavalry horses, but since then they have been ground and sold on a commercial scale as food for livestock in the Islands.

Several chapters are devoted to advocating more extensive planting of nut trees and to greater consumption of their fruits as human food. Acorns, particularly those of *Quercus Ilex* in southern Europe, have long been used in this way, and in western North America several species native to that part of the world yielded food for various tribes of Indians. The Persian or English walnut, *Juglans regia*, is one that has already been extensively developed and planted for human food, but the world awaits comparable development of improved strains through breeding and selection in the various other species of walnut, butternut and hickory. Pecans provide an outstanding example of what can be accomplished in this direction.

Other potential tree crops of the North Temperate zone that merit greater attention than they have so far been accorded, if any attention at all has been paid to their potentialities, are beechnuts, pistache, the nut-bearing pines, almonds, apricot nuts, cherry-tree nuts, filberts, soapnut, holly, ginkgo, papaw, horse chestnut, osage orange, sugar maple, privet, Queensland nut, argania, wattle, tung, wild plums, chokecherries and sand cherries. In Professor Smith's own words, "No botanist, only God, knows how many more trees might become crop trees if man did his best with them".

The concluding chapters are devoted to the economics of tree crops, to an accounting of what has been done in developing them and to other aspects of the matter. Considered as a whole, the book provides extremely interesting and informative reading, for it is well written and is permeated by a contagious enthusiasm for departure from traditional soil-destroying annual-crop agriculture on hilly terrain to that of soil-retaining tree crops. There may be fallacies in the arguments presented in defense of these ideas, economic factors in various parts of the world may not yet permit the shift, and there may be good reasons, unknown to both the author and the present reviewer, why the idea of tree crops has not already been further developed. Nevertheless, the attention that is directed to the matter by this volume is a distinct contribution and, it is hoped, will stimulate the breeding and other research called for.

The critical reader of this book is urged to continue through it and not to be antagonized by two or three features that may give him a premature notion that the volume is not worthy of sustained reading. One of these features is that the present edition, though urging tree crops in the year 1950, has retained from the first edition of 1920 certain cost and revenue figures from the year 1913 which, of course, are so antiquated as to have no merit today. Secondly, the reader may be annoyed by the fact that the author, in making certain assertions of simple facts, instead of merely stating them, chose to quote personal letters or other sources 40 years or more old. The most extreme example of this is that in giving the natural distribution of mesquite in the American Southwest, the author, instead of simply stating the matter, as it may be learned from any one of many modern sources, chose to quote four lines from an army doctor in the year 1884! The reader may also wonder why the author discusses the same tree, *Prosopis juliflora*, in two separated chapters and under different common names, though he recognizes that the same species is under consideration in both chapters. Perhaps the present reviewer misunderstood the author's intentions in these statements, but he is thankful that these anomalies did not prevent him, as they nearly did, from reading the entire volume.

A Natural History of Trees of Eastern and Central North America. Donald Culross Peattie. xv + 606 pages; illus. Houghton Mifflin Co. 1950. $5.

With ten or more volumes already to his credit, one of which, American Heartwood, has been reviewed in ECONOMIC BOTANY (Vol. 4, No. 1), Mr. Peattie has undertaken the preparation of a series of books on the trees of North America, north of Mexico. The present volume is the first of that series. If the others to follow are of comparable quality they will all provide very delightful popular reading on the North American tree flora, for they will combine a very pleasing literary style with the accuracy of statements that is so often lacking in books of this type. Beautifully executed pen and ink drawings by Paul Landacre and a key to the more than one hundred kinds of trees considered,

as well as a glossary and index, are valuable supplements to the very readable accounts of all the species, and each of them is accompanied by notes on popular synonymy, range of distribution and identifying characters. But it is for readers interested in economic botany, especially in its historical aspects in early American development, that these books should have particular appeal, for, judging by this the first of them, they will be a source of considerable information in this direction.

Eastern white pine is given the longest account of any tree in the book, twelve pages, for historically it has been the most noteworthy of American trees. In the early colonial days when England really was mistress of the seas and forever at war with the other navies of the world, the masts of her ships were pieced together and made of Riga pine (*Pinus sylvestris*), but Prussia, Russia and Sweden held monopolies on the supply and the Danes could easily have cut off access to them. No wonder, therefore, that the tall straight boles of white pine, single trunks of which were long enough to make the tallest masts, were a great boon to the English navy. John Wentworth of New Hampshire sold great mast sticks for as much as £100 apiece and " was made Surveyor General of His Majesty's Woods in America, with authority to mark for the Navy Board every great Pine in America, with a blaze known as the King's Broad Arrow ". Stringent laws were enacted protecting such trees for the Crown, but the violations of such laws were not the least among the disputes between the King's men and the colonists that preceded the Revolution.

Among the 20 other coniferous trees considered in the book, one learns that the heartwood of red pine was specified by the early shipbuilders for the decks of wooden vessels, that pitch pine charcoal fed the hundreds of small forest forges in the pine barrens of New Jersey which forged weapons for the colonists, and that " long before the white man came, the Indians used the roots of Tamarack for sewing the strips of Birch bark in their beautiful canoes. The best roots came from trees in beaver ponds, for they were especially tough, pliant, slender, and elongated. When the white man began to build his own boats, he sought out Tamarack roots for a very different purpose. He used them for ' instep crooks ' or ship's knees—that is, a solid piece of durable wood with a natural angle or bend. Such bends were found in the roots of Tamaracks which grew in shallow mud underlain by a hardpan clay that deflected the growing roots at a sharp angle. However, only small knees are ever made by Tamarack; the great knees of the sailing ships were got out of Southern Live Oak and Eastern White Oak ".

Among the more than 150 kinds of hardwood described in the book, the reader learns that " in Revolutionary and pioneer times Willow was much employed in the making of a fine charcoal for the black gunpowder of those days " and that for gunstocks black walnut " was, and is, unsurpassed, since no other wood has less jar or recoil; it never warps or shrinks; it is light in proportion to its strength, never splinters and, no matter how long it is carried in the hand, will not irritate the palm, with its wonderful satiny surface. In every war, the United States Government has made a fresh raid upon Black Walnut for gunstocks ".

Similar utilization notes, some longer, others shorter, accompany the accounts of most other species. To select only two of them for notice here, it may be noted first that:

" The inner bark of Basswood yields some of the longest and toughest fibers in our native flora. It was stripped by the Indians in spring, and thongs prepared from it without further processing. Good rope, however, was made from it by retting—keeping the bark under water for about a month, until the soft tissues should rot away, leaving the somewhat slippery fibrous tissue. Or sometimes the bark was pounded, or simmered in wood ashes, in a kettle. Long strips of rope or string were then twisted to form cordage, which the Indians used to insist was softer on the hands when wet than the white man's hempen fibers, and was not so liable to kink. Thread of Basswood was used to stitch together the mats made of cat-tail leaves, and the bark, perhaps because of its mucilaginous qualities, was used to bind up the warrior's wounds. Some of the Iroquois' masks were carved in the sapwood on the living tree, and then split off from the trunk and hollowed out from behind ".

The reader is informed elsewhere that:

" Fully 90 per cent of the Dogwood cut in the last century has gone to the making of

shuttles in the textile industry. When the shuttle was thrown from hand to hand by the weaving woman, almost any wood might do, but with the invention of mechanical looms, where the shuttle is hurled at top speed, carrying the weft thread, the shuttle is in continual contact with the threads of the warp. So a wood must be used which will not crack under continuous strain and will wear smoother, not rougher, with use. Walnut wears smoother, but is too weak. Hickory in stronger, but wears rough with usage. Dogwood is ideal. Yet it did not come into much use while Turkish Boxwood was plentiful. Then, about 1865, the roller-skating craze began to absorb the market for Box, and Dogwood came to the fore. Cut in the South, it was manufactured and used in New England or exported as logs from the southern seaports to Britain, France, Germany, Italy, and Switzerland. Soon it was found cheaper to ship the manufactured article, and most Dogwood shuttles are now made in small but numerous mills in the South ".

Not all utilization accounts in Mr. Peattie's book, admittedly, are so explicit as the foregoing, for there is not so much to be said about the uses of many other woods. As a general survey, however, of such usage, as it has developed since Colonial days in America, the reader would have difficulty in finding a more readable account than is contained in this, the latest of Mr. Peattie's works.

Mushrooms in Their Natural Habitats. Alexander H. Smith. Stereo-photographs by Wm. B. Gruber. Vol. I—Text: xiv + 626 pages. Vol. II—Illustrations: 231 16-mm. Kodachrome stereo-transparencies, mounted in 33 View Master Reels with a View Master Stereoscope. Sawyer's Inc., Portland, Ore. 1949. $26.

One of the most novel and praiseworthy innovations in the field of publications on natural history is this two-volume, handsomely bound work on the mushrooms of the United States, in which there is combined the technical knowledge of an outstanding authority in mycology, the exquisite colored stereo-photographs of an expert photographer and the skill of publishers who have combined the three elements into a work that can hardly fail to be followed by similar publications in other branches of science.

Dr. Smith is Associate Professor of Botany at the University of Michigan and Editor-in-Chief of Mycologia, the official publication of the Mycological Society of America. In Vol. I he has provided both popular and technical descriptions of all the species so exquisitely pictured on the reels in the other volume, and has included notes on the edibility of nearly every one of them. In addition to these economic considerations there are a chapter on mycophagy, that is, the matter of poisonous fungi and the art of recognizing, collecting and preparing edible forms; and lists of edible and poisonous mushrooms in the three large areas into which the United States is divided for the purpose. It is particularly interesting to note that these lists refer to 17 edible and 13 poisonous species in the northeastern and central U.S.; 16 edible and 11 poisonous species of the Rocky Mountain States; and 22 edible and 11 poisonous species of the Pacific Coast States. A general key for identification purposes and chapters on various aspects of mushroom study are also included in the first 135 pages of the book, whereas the concluding pages include a bibliography, a glossary and, of course, the index.

For those especially interested in the gastronomic aspects of mushroom study, Dr. Smith has the following to say:

" According to recent studies of mushroom poisoning, the Amanita-type (obtained from *A. verna* and its relatives) far overshadows all others in severity and importance. Consequently it is very essential for every collector to learn to recognize the genus *Amanita* and, if possible, to learn the common species. This is the best insurance one can have against making the serious mistake of confusing them with the species of other genera ".

" The poisoning produced by species in other genera of mushrooms is generally less serious than that caused by the poisonous amanitas but one can experience a very bad night as the result of a misidentification. The types of poisoning have recently been grouped into about ten categories based for the most part on the symptoms produced. The effects may be most evident in the cell tissue, the nervous system, the intestines, the blood, the muscular fibres, the lungs, etc. Some species produce more than one type of symptom, and *Lepiota helveola* produces a type much like that of the deadly amanitas

but not as severe. The personal factor in mushroom poisoning is very important and people who know they are violently allergic to fungous spores, *i.e.*, some 'hay fever' patients, would do well to be very cautious when first testing any kind of mushroom not previously eaten by them. There is a distinct possibility of the novice coming to grief as the result of eating some well known edible species because of an unusual personal idiosyncracy on his part. For this reason the warning to eat only small quantities the first time one tries a species has to be repeated over and over again".

With respect to conflicting reports on the edibility vs. poisonous nature of some mushrooms, the author points out that biotypes within species and chemical rather than morphological differences may account for such erratic cases. This may explain the persisting assertion in the literature that "*Coprinus atramentarius* does no harm to those who do not use alcoholic beverages at the time or shortly after the mushrooms are eaten, but that those who do may be in for a bad time". Reports of erratic cases of poisoning by *Helvella esculenta* might be accounted for in the same way.

The Kodachrome illustrations that make up Vol. II of this work defy description; they must be seen to be appreciated; and when once seen, they cannot fail to stimulate the wish that the identification of all natural objects, difficult to describe, might be similarly portrayed. Apart from the cost of such publications, there are of course other limitations, but it is certainly to be hoped that the latter will be overcome in order that this technique may be applied elsewhere.

Introduction to Agricultural Biochemistry. R. A. Dutcher, C. O. Jensen and P. M. Althouse. xii + 502 pages. John Wiley & Sons. 1951. $6.

While this book is primarily a textbook of chemistry, presuming a basic knowledge of both inorganic and organic chemistry on the part of the reader, it does contain references to some industrial applications, particularly one chapter entitled "Farm Chemurgy". This chapter points out, to begin with, that "during the world depression in the late nineteen-twenties and the early nineteen-thirties, American farmers were faced with large surpluses of agricultural products for which there were no markets. As a result agricultural and industrial scientists and Government officials became interested in finding ways and means of helping agriculture dispose of these surpluses at prices that would cover cost of production". Dr. William J. Hale of the Dow Chemical Company was among those who gave thought to the matter, and he coined the term "chemurgy" which has since developed to mean the application of chemistry toward the greater utilization of farm products. As a result of interest stimulated by Dr. Hale, Wheeler McMillen and others, there was organized the National Farm Chemurgic Council, and Congress established four Regional Research Laboratories at a cost of about $8 million dollars to develop the industrial utilization of farm crops. The Council has since been publishing Chemurgic Digest, articles in which are frequently abstracted in ECONOMIC BOTANY, and the Regional Laboratories are often referred to in these same pages.

After pointing out that indigo farming in India has been completely abandoned since natural indigo has been replaced by the synthetic product; that natural ascorbic acid, formerly extracted commercially from Hungarian peppers, is now manufactured synthetically in ton lots; and that the present dependence of the insecticide industry on agriculture for pyrethrum may sometime be superseded by synthetic pyrethrins; the chapter continues to say that "nevertheless many phases of farm chemurgy have been and will continue to be economically successful, to the mutual benefit of the farmer, the industrialist, and the ultimate consumer". And in expansion of this thought the chapter gives brief information on various vegetable oils, on industrial products made from natural sugars and starches, on various fibers and on a number of other industrially important products derived from agricultural crops wholly apart from the food that they provide.

The Wealth of India. Vol. II. Written by several contributors, published by the Council of Scientific and Industrial Research, 20 Pusha Road, Karol Bagh, New Delhi, India. xx + 427 pages; illus. 1950. 40 shillings.

In December, 1948, the world's literature on economically important plants was greatly enriched by the publication of Vol. I of this proposed encyclopedic work on the natural resources of India. That volume was re-

viewed in ECONOMIC BOTANY, January–March, 1950, and this journal now takes pleasure in calling attention to the publication of Vol. II of The Wealth of India in November, 1950. It contains 175 pages more than the first volume and covers only the letter C from " cabbage " to " cytisus " in the same authoritative and excellently edited manner. Plants and plant products again occupy the entire volume—several hundred species in 230 genera—almost to the exclusion of other articles, of which there are only eight important minerals and seven animal products.

As was done in connection with Vol. I, it seems most suitable in the present case, where again there is such a wealth of information, to call attention to the principal genera discussed, to their products and to the number of pages devoted to them.

Caesalpinia (4): tannin, dyes, drugs
Camellia (25): tea
Cannabis (6): hemp fiber, drug
Capsicum (5): spice
Cassia (5): drugs, tannin
Chrysanthemum (6): insecticide pyrethrum
Cinchona (10): quinine
Cinnamomum (10): camphor, cinnamon, oil
Citrus (20): edible fruits and their oils
Cocos (27): coconuts, oil, fiber
Coffea (16): coffee, oil, wax
Corchorus (20): jute fiber

ECONOMIC BOTANY looks forward to calling attention to the publication of each of the subsequent volumes, and hopes that this great work will receive the wide acclaim that it merits.

The Clove Tree. G. E. Tidbury. xi + 212 pages; illus. Crosby Lockwood & Son, Ltd., London, England. 1949. 18/-.

The world's demand for cloves is a little over 12,000 tons per annum, and until recent years nine-tenths of this amount was furnished by the little islands of Zanzibar and Pemba, situated a few miles off the coast of Tanganyika Territory in equatorial East Africa. For a century and a half production of cloves has been the most important industry in the Zanzibar Protectorate, which still furnishes three-quarters of the world's needs, and other areas of production today are Madagascar, the Mascarene Islands of Seychelles and Reunion in the Indian Ocean, the East Indies and Malaya. The history of this industry, the agronomy of the crop and practically every other aspect of its production, care and utilization are discussed in this moderate sized book.

Cloves are the dried unopened buds of clove trees, and for 2,000 years they have been among man's most important spices. Their earliest use by court officials who sweetened their breath with them whilst addressing their ruler is recorded in Chinese books of the Han period dating from 220 to 206 B.C.

Today cloves are used principally in three ways. First, as a spice; secondly, as a stimulant by chewing and smoking; and thirdly, by distillation and manufacture into a variety of chemical products. Usage as a spice in the New World is well known, and such utilization of the dried buds in Oriental countries is even greater. In the East cloves and other spices are often added to chewing tobacco, but in Java they are added to smoking tobacco for commercial manufacture into cigarettes. They are also added to the famous betel-nut chew of the Orient.

Whatever the use, it is dependent upon the plant's production of clove oil, 16% to 19% being the content in the buds, 5% to 6% in the bud stems. The oil is extracted by distillation of either the cloves or their stems, and at present the entire crop of stems is distilled in Zanzibar and only the oil exported. About 85% of the oil is the ingredient eugenol, a commercially valuable product that may be obtained also from the oils of bay, pimento, cinnamon, ylang ylang and patchouli. Its most important commercial use is in the manufacture of perfumes, but it also serves as raw material for conversion into the flavoring substance vanillin which is identical with the product of the true vanilla vine. These and other uses are discussed in the concluding chapter of this little volume that deals with one of the oldest of plant products used by man and one which, centuries ago, was the basis for international rivalries and hostilities.